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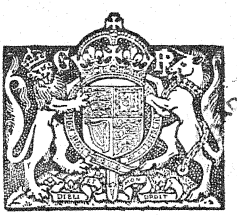

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CONTENTS

VOL. XVI

CONTENTS

STUDIES IN THE *JOWARS* OF GUJARAT.

I. THE *JOWARS* OF THE SURAT DISTRICT.

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INTRODUCTORY.

The sorghum or *jowar* crop is, with the solitary exception of rice, the most important of all those cultivated in India. In the Bombay Presidency it stands easily first of all, and if we include Sind, its annual area approaches eight million acres. In the Bombay Presidency proper, its cultivation reaches 6½ million acres annually. Of this enormous area, the British Districts of Gujarat claim only a little over 8 per cent., and yet in all of these Districts (except Kaira and the Panch Mahals) the *jowar* crop is one of very great importance.

In the Surat District which represents the southern extremity of the Gujarat *jowar* area, almost the whole of the crop is grown in the *kharif* season, and its distribution is shown in the following Table of area by talukas (based on the record of 1922-23).

TABLE I.

Distribution of Jowar in the Surat District.

Taluka	Area 1922-23	Proportion of cropped area
	Acres	Per cent.
Chorasi	15,705	28·2
Olpad	22,862	18·2
Mandvi	19,062	16·6
Bardoli	19,451	13·9
Jalalpur	12,778	15·9
Chikhli	3,209	3·2
Bulsar	67	0·0
Pardi	10	0·0

The Surat District, as will be seen from the above table, clearly passes out of the typical *jowar* region in the south where the rainfall is too high for its cultivation to prevail, and where it is replaced by rice. In the more northerly parts of the District, with a rainfall of 40 inches, all received between the months of June and October, and with a heavy black soil, there appears a region particularly suitable for this crop, and especially for the varieties which have a long period of growth, yield highly, and give also long and heavy straw. In fact, the types of *jowar* commonly grown in Surat are among the latest (that is to say, they have the longest period of growth) in India. They ripen in from four to six months. The varieties grown differ, however, very markedly in this respect, and thus vary in their suitability for growth according to the character of the season.

In the Surat District, *jowar* is always rotated with cotton, and its sowing is generally delayed until the cotton has been planted. If the land becomes foul with weeds during this period, it is ploughed and harrowed before sowing. The delay is necessary, for if *jowar* be sown at the beginning of the monsoon, it is always very severely attacked by one of the borers (*Chilo simplex*, *Sesamia inferens* or the anthomyid fly borer). It is usually sown by drill in rows two feet apart in the middle of July in heavy black soils, while in lighter soils it is put in a little earlier. After four to five weeks, the crop is thinned to a distance of one foot between the plants. The seed rate used is five to six pounds per acre, and it is often sown mixed with two to two and a half pounds of *tur* (*Cajanus indicus*) and a few ounces of *mung* (*Phaseolus mungo*) and *chavli* (*Vigna catiang*). During the younger stages of the growth, the most serious danger lies in the attack of the borers mentioned above, which begins from two to three weeks after germination and is particularly serious in a year of heavy and continuous rain. As a result, it is wise to sow thickly and to thin out the affected plants. Inter-cultivation is given with the blade harrow.

The crop grows very vigorously from September, that is to say, from eight weeks after sowing, and the earheads appear from the last week in October. Absence of rain in September is injurious, but rain in October is believed to give small earheads and reduce yield : north-east winds in December hasten the ripening.

Reaping is done in January when the topmost leaf (flag) dries up and turns yellow, and is started early in the morning (5 a.m.), when there is dew, to avoid dropping of leaves. The bundles are arranged in conical heaps in the field for drying and then the earheads are cut off, carried to the threshing yard, dried for a few days and threshed. The average yield per acre is 720 lb. of grain and 1,200 lb. of dried fodder.

The main enemies of the crop are the borers afore mentioned, which, at Surat, as tested near the end of October, have given a percentage attack as follows in four successive seasons.

1922-23	72 to 87 per cent.
1923-24	20 ,,
1924-25	65 ,,
1925-26	47 ,,

Jowar Varieties of the Surat District.

The varieties of *kharif jowar* generally grown in the Surat District are five in number. Of course, there are a number of minor types grown in odd places but those of which a short description is now to be given comprise all that are at present of any practical importance. These are :—

1. *Perio Jowar.*

This is the main variety grown in the Surat District, occupying more than three-fourths of the total area. It is also called '*bhar*' or '*deshi*' and its characteristic feature (from which it takes its name) is the pearly yellow colour of the grain. It varies very much in the character of the plant and especially in the character of the earhead. Thus there are types known as *Fafar* with loose earheads, generally consisting of tall plants with long peduncles and erect heads, liable to lodge and usually with low yield. Other types are known as *Budh-perio* with compact heads, usually possessing short and thick internodes on the stems. Another kind is known as *Moni Timberwa* or *Deshi* with larger though softer grain than ordinary *Perio jowar* bringing a higher price. The heads in this kind vary considerably in compactness. A fourth type is *Perio Sholapuri*, intermediate between the Perio and Sholapuri varieties. And finally, there is *Agio jowar*, a kind resistant to the *striga* pest, sometimes known as *Khaplatio Nialo*, largely consisting of white ribbed plants, said to ripen early even when sown late.

From this description it will be seen at once that the so-called *Perio jowar* is a mixture of types, whose almost only connection is the pearly character of the grain. To take only one or two characters as tests. It was found that there is a very clear distinction between plants with a green midrib of the leaf and plants with a white midrib. The latter always have a pithy stem. In 1924-25 a sample of local *Perio jowar* seed gave 55 per cent. of green midribbed and 45 per cent. of white midribbed plants. In 1926-27 various samples gave 55·5, 82·0, 95·0, and 64·3 per cent. of green midribbed plants respectively. A type mass selected on the Surat Farm for a number of years gave 96·6 per cent. of green midribbed plants.

Another difference, easily recognisable, is in the colour of the anthers after weatheration. Surat Farm selected *Perio jowar* in 1922-23 gave 93·0 per cent., and in 1926-27 gave 95·7 per cent. of red anthered plants. Local *Perio jowar* in 1925-26 gave only 35·0 per cent. and in 1926-27 gave 39·7 and 42·0 per cent. of red anthered plants. A lot of seed known as *Agio jowar* gave, in 1926-27, 37·6 per cent. of red anthered plants.

Judged by either of these very simple tests, the extreme heterogeneity of the material grown under the name of *Perio jowar* in Surat is very apparent.

2. *Sholapuri Jowar.*

Nothing is certainly known as to the origin of this type of *jowar*, but it is commonly believed that it was introduced from the Deccan either during or after the

famine of 1899-1900. Its main characteristic is that it can be sown later than the ordinary types, and it ripens earlier and gives a large yield. It grows quite well if planted in September. It occupies one-eighth of the total *jowar* area in Surat. The fodder is largely pithy (the plants having a white midrib) and is thus poor. An actual field examination in 1925-26 gave 99·3 per cent. of white midribbed plants. It is said to do well in the lighter soils or on sloping black soils, where less water is retained. It is apt to lodge, more than any other of the local types. The earhead is nearly always loose, and is distinctly conical when it first appears (Plate I). The anthers are very rarely yellow in colour, but brown and red anthered types are common.

3. *Chapti Jowar.*

This variety is grown to a limited extent on highly retentive *besar*, or alluvial clay soils. It thrives under heavy rainfall conditions. The grains are very large, flat, soft and white, and so bring about Rs. 7 to 8 more per *galli* (1,140 lb.) than the *Perio jowar*. The grains being soft and mealy are, however, easily attacked by weevils. The earheads are all semi-compact. The chaff is small in amount. The fodder is preferred for softness.

This variety also includes many varying types. The best known as *Telia-chapti* is grown in Baroda territory near Bardoli and Nior, and brings from Rs. 10 to 12 per *galli* more than ordinary *Perio jowar*. In this variety plants with white midrib are very scarce, and thus the straw (*Kadbi*) is very highly valued. Types with red or brown anthers are found varying from 4·8 per cent. of the plants on the Surat farm to 1·8 per cent. in the ordinary crop.

4. *Nialo Jowar.*

This jowar is a type which can be planted late, say in August, September or even up to the middle of October. It is often sown in fields where rice would normally be planted, but where rice cannot be grown owing to a dry season. When put in in October, it grows quickly, flowers within sixty days, and yields a good crop. It is, however, more especially useful as a fodder variety and does not grow very tall. The earheads are always loose on long straight peduncles.

The plants of this variety bear only six to eight small leaves, and are thin stemmed, and its area fluctuates much from year to year. It is said to be largely immune to the striga pest. Almost all the plants have red or brown anthers, some samples giving nothing else, while one field counted gave 93·2 per cent.

5. *Vani Jowar.*

This is a type of *jowar* used for parching in the green condition, and is often grown simply as a few rows in a field. The colour of the ripened grain varies, however, very widely, but the wrinkled seeds, pitted at the tips, are very characteristic. The ripened grain is somewhat flinty.

The leaves in this variety are generally very erect and the midribs are generally white.

Typical samples of the grain of four of these varieties gave the following figures on analysis.

—	Budh Perio	Chapti	Sholapuri	Vani
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	11·7	11·8	11·4	11·0
Ether extract	3·1	2·7	3·6	4·3
Albuminoids	8·2	6·5	6·5	10·5
Digestible carbohydrates . . .	74·4	76·1	75·9	69·2
Woody fibre	1·3	1·2	1·1	2·4
Ash	1·3	1·7	1·5	2·0
	100·0	100·0	100·0	100·0

To the north of the Surat *jowar* area, lies the large *jowar* growing area of Broach, but in this latter District the jowars cultivated are almost all *rabi jowars*. These latter can be readily distinguished, even in appearance by the fact that the leaves are completely glabrous, that the leaf sheath does not completely cover the internode, that the midrib is always green, that the earheads are usually very highly compact, that they ripen much more rapidly than either *Perio*, *Chapti*, or *Sholapuri* and that they are very much less liable to weevil attack than the *kharif jowar* of Surat. The seeds are generally smaller and lighter than those of the *kharif* crop.

Among the Surat varieties themselves, the most obvious differences are :—

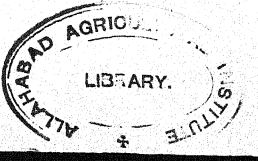
(*a*) The difference in colour of the midrib (green and white), the latter indicating a pithy stem. *Sholapuri*, Vani and *Khaplatio-Nialo* have white midribs ; *Chapti* has green midribs ; *Perio* has both in varying quantity.

(*b*) The difference in size of plant :—*Nialo* is a small plant with few small leaves.

(*c*) The difference in hairiness of leaf :—*Chapti* is a less hairy type, especially near the midrib of the leaves.

(*d*) The difference in compactness of earhead :—All stages of compactness are found in *Perio*. In *Chapti* all are semi-compact, while in *Sholapuri* and *Nialo* the earheads are generally loose.

(*e*) The difference in length of the peduncle :—This being longer in *Sholapuri* and *Nialo* than in *Budh-perio* and *Chapti*.



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(*e*) The difference in length of the peduncle :—This being longer in *Sholapuri* and *Nialo* than in *Budh-perio* and *Chapti*.

(*f*) The difference in anther colour :—This varies much in all varieties but in *Sholapuri* and *Nialo* red and brown anthers are found in by far the majority of cases.

(*g*) The difference in grain size and colour :—This has been already described.

Almost all these differences, except those of colour, are differences of degree.

Botanical Characteristics of the Jowar Plant.

In the present section, it is proposed to take a number of the botanical features of the *Jowar* plant, and consider the variations which occur in them, as illustrated by the *Jowars* of the Surat District.

Stem. In a normal season, all the three main Surat *Jowar* varieties—*Perio, Chapti, and Sholapuri*—have from seven to twenty-two nodes, the total height varying from 60 to 220 cm. with an average of about 150 cm. The *Sholapuri* variety is not so tall as the others owing to a smaller number of nodes, but on the other hand, the upper nodes are usually longer in this case.

The *Jowar* plant has a series of short internodes at the base, has the longest internodes in the middle of the stem, while the top internodes are generally longer than those at the base but not so long as those in the middle. If, however, the crop in Surat is sown very late, say in September, then the top-most internodes (say five in number) tend to be the longest, the middle ones standing next.

In all the standard Surat varieties the maximum internodal circumference of the stem is 2·5 to 4·3 cm., with a diameter of 1·2 cm. In very early flowering types, the stem is always thin.

Leaves. The leaves occur in two opposite ranks, and are acute at the apex, broadest above the middle, somewhat narrowed at the base. The fourth leaf from the top represents, fairly closely, the average leaf. The length in the Surat varieties varies from 40 to 60 cm., and the greatest breadth from 5·4 to 8 cm.

Some types of *Jowar* have the leaves almost completely glabrous. Others are very hairy. The hairiness is most seen in the upper half of the leaf, though when the leaf is fresh, it is seen all over the lower half of the ventral surface. In *Chapti jowar* there is the curious variation that at the tops of the leaves the hairiness (Plate VI) is emphasised near the midrib, while this is not the case as one proceeds towards the base, and the hairs get sparse on both halves. In *Perio jowar* hairiness is far more evenly distributed over the two halves of the leaves.

What purpose the hairs serve is quite unknown. By many workers they have been claimed as a means of drought resistance, but the evidence for this is very slight. The hairs can best be seen with a lens when the flag of a leaf is just out, between 9 and 11 a.m. As the leaf gets older, the hairs drop off. On the ligule, there is always a thick mass of long hairs.

On the leaf sheaths, there is generally found a deposit of wax, in the case of the upper four or five leaves, but the amount of this deposit is very variable. It is

extremely developed on one of the pure strains which the authors have isolated (*Althan Deshi* 6) to be afterwards described. What its purpose is, is very doubtful. Haberlaudt[1] considered it as a means of increasing the effectiveness of the control exercised by the epidemis on transpiration. In the case of wheat, on the other hand, Bhide[2] has claimed that absence of wax and capacity for vigorous growth were positively correlated. In the case of *Jowar* at Surat, the wax was found to have a specific gravity of 0·893 at 26·5° C. and had a melting point of 83° to 85° C. It darkened much on melting. It was soluble in ether, but practically insoluble in alcohol, benzene, or chloroform. As scraped from the plants, it gave 9·25 per cent. of ash.

The Inflorescence. The *Sorghum* or *Jowar* inflorescence is a panicle, usually called the head. The heads differ widely in shape. The central axis is usually angular, and the side branches are in apparent whorls. The lower branches in the panicle are, however, irregularly arranged, and only about an inch from the bottom do regular whorls appear. The distance between the whorls is usually greatest in the middle of the earhead.

On the panicle branches, the spikelets usually occur in pairs or occasionally in threes; towards the tips of the branches and branchlets, they almost invariably occur in threes. Invariably, one of the two or three is sessile and hermaphrodite, while other one or two, as the case may be, are pedicelled and either empty or staminate. The sessile or hermaphrodite ones are broad, thick and fertile; the pedicelled ones are narrow and long.

In an average season the fertility of the earhead in Surat *jowar* is very nearly complete, except for a few failed flowers at the base of the earhead. These may be taken at 10 to 15 p.c. of the total heads as a rule. In some years, however, a larger failure occurs, and one such year was 1926-27 when the percentage of failure rose to 15 to 20 per cent. of the heads. A detailed examination of heads of two pure types of *Perio jowar* (*Althan Deshi* 6 and *Budh-perio* 53) was made, with the following results.

Althan Deshi 6.

(1) *Normal main shoots.* (45 earheads with such failures examined) Nearly 60 per cent. of the earheads had patches of failed flowers at the base, say within one inch of the bottom; 22 per cent. had similar patches in the lower half of the heads; 18 per cent. had patches of failure right even to the top, though their frequency increases when descending the ear.

(2) *Shoots from stubbles and tillers.* (40 earheads examined) The base only was affected in 13 per cent. of the cases; 22 per cent. had similar patches on the lower half only; nearly 65 per cent. had patches of failure all over the earhead.

(3) *Shoots from axillary branches.* (20 earheads examined) The flowering of these shoots was late. There were no cases where the failure was limited to the

[1] Haberlaudt. Physiological Plant Anatomy, page 107.
[2] R. K. Bhide, *Annual Report, Bombay Department of Agriculture* 1920-21, page 118.

base or lower half of the earhead, but 35 per cent. of the earheads had small patches of failure all over.

Budh-Perio 53.

(1) *Normal main shoots.* (40 earheads with such failures examined) Nearly 55 per cent. of the earheads had patches of failed flowers at the base ; 25 per cent. had such patches in the lower half ; and nearly 20 per cent. had patches all over.

(2) *Shoots from tillers and stubbles.* (40 earheads examined) The base only was affected in 35 per cent. of cases ; 15 per cent. had similar patches on the lower half only ; 50 per cent. had patches of failure all over the earhead.

(3) *Shoots from axillary branches.* (20 earheads examined) The heads of these shoots showed 20 per cent. with small patches all over the earhead.

The only clear indication from this examination is that failure on the lower part of the earheads is more likely to occur than in the upper ; though the percentage of non-fertilized flowers in such heads is low, *viz.*, 1 to 4 only.

Glumes. The lemmas of the fertile flowers in the Surat varieties of *jowar* have awns, while the staminate or empty flowers are awnless. The awns attached to the lemmas of fertile flowers in different varieties were measured from one hundred spikelets and showed an average length of 1·13 cm. with *Chapti jowar*, and 1·15 cm. with *Sholapuri jowar*. *Vani jowar* gives figures very close to those for *Chapti jowar*. The awns in *Perio jowar* are much shorter, 100 flowers of *Budh-Perio* giving 0·84 cm. as the mean awn length. There appear to be characteristic differences in the variation of the outer glumes. In *Chapti jowar* there is an average of 11·5 veins per glume ; in *Budh perio* 10·6 veins and in *Sholapuri* 9·6 veins. In the *Budh-perio jowar* the veins extend to the edge, and are clearly marked at the top of the glume and the glumes are very hairy ; in *Sholapuri* the veins extend further downward, but the glumes are much less hairy ; while in *Chapti* the veins almost reach the base of the glumes, and the latter are still less hairy than with the *Sholapuri* type.

In shape the outer glumes are roundish at the top, and broad in relation to length in the *Perio* type ; in the *Sholapuri* kinds they are more tapering and relatively longer. The *Chapti jowar* has glumes longer than the *Perio* and broader than the *Sholapuri* types.

Coloration of the anthers. When the grains begin to ripen, the anthers are seen on the earhead in a shrivelled condition after weatheration. Well marked colour differences can be found in this condition in different varieties and strains. In all there are two main divisions of this anther colour, that is to say, the anthers are either yellow or red ; though the shade of each varies a good deal. This character is very important in recognising different strains of a variety, and the following notes were made in 1923-24 and 1924-25 by one of the authors.[1]

[1] Patel, G. B. Extent of natural cross-fertilization of *Jowar* at Surat *Agricultural Journal of India*, Vol. XXI, page 366.

" In 1923-24 the seed obtained from mother earheads with red anthers either gave entirely flowers with red anthers, or else flowers with red and yellow anthers in a proportion of 2·9 to 5·3 to 1. When the mother plant had yellow anthers, the progeny bred true in this respect. This latter observation was confirmed in 1924-25, but again some red or brown anthered plants gave very variable results, red or brown anthers being more numerous than yellow in a proportion which varied from 1·7 to 4·1 to 1."

The relationship of colours of anthers to colour of stigma was studied in 1926-27. In the case of a strain of *Budh-perio* marked No. 53, which is a red-anthered type, eighty-five plants were examined in this connection. Out of these 9 had light brown anthers and 76 had distinctly red anthers. All the distinctly red anthers had also the shrivelled up stigma of a red colour. The nine plants with light brown anthers had light coloured stigma. A similar association of colours was found with plants of the *Sholapuri* type and with other strains of *Budh-perio jowar*. In the case of yellow anthered types the stigma is likewise whitish yellow to yellow in colour.

Variation in the number of pedicelled staminate flowers. It has already been noticed that the spikelets usually occur in pairs or in threes, one of which is sessile and hermaphrodite and the others are pedicelled and either empty or purely staminate. The interest in these staminate flowers was increased by the discovery of a great variation in the amount of cross-pollination. The question arose, in fact, how far the proportion of such staminate flowers varies from strain to strain and how far this variation has anything to do with the extent to which cross-pollination takes place. A single earhead of seven different strains, grown in pure condition for several generations, was dissected, and the relative proportion of different types of flowers determined in 1926-27. The results are shown in the following Table :—

TABLE II.

Variation in the number of staminate flowers.

	Strain and variety						
	Althan Deshi 6	*Budh Perio* 9	*Mori Timbervea* 7	*Budh Perio* 40	*Chapti* 8	*Sholapuri* 21	*Sholapuri* 1
Hermaphrodite flowers per head . .	2,354	1,846	1,459	1,918	1,116	1,725	2,387
Pedicelled flowers per head . . .	3,242	2,345	1,894	2,443	1,506	2,261	3,082
Proportion of pedicelled to hermaphrodite flowers.							
(Hermaphrodite flowers-1) . . .	1·38	1·27	1·30	1·27	1·34	1·31	1·30
Proportion of hermaphrodite flowers with *one* pedicelled flower attached, in percentage.	60·2	68·3	64·8	67·1	58·8	67·7	68·5
Proportion of hermaphrodite flowers with *two* pedicelled flowers attached, in percentage.	38·7	29·4	32·5	30·2	38·1	31·6	30·3
Proportion of hermaphrodite flowers with *no* pedicelled flower attached to it, in percentage.	1·1	2·3	2·7	2·7	3·1	0·7	1·2
Proportion of pedicelled flowers which have anthers in percentage.	40·0	23·5	19·4	3·4	0·9	0·2	0
Proportion of pedicelled flowers which are empty, in percentage.	60·0	76·5	80·6	96·6	99·0	99·8	100

It will be seen from the above analysis that the importance of the pedicelled staminate—flowers is very different in different varieties and strains. The first three strains in the table, *Althan Deshi 6*, *Budh Perio 9* and *Moni Timberwa 7*, are all compact headed types, though *Budh Perio 9*, is less compact than the other two. *Budh-Perio 40* and *Chapti 8* are what may be called semi-compact types, while the earhead of the *Sholapuri* strains would be classed as loose. It is at once clear that the compact types all of which belong to the *Perio* variety have a very much larger number and proportion of pedicelled flowers with anthers, or, in other words, of staminate flowers. In the case of the *Chapti jowar* type examined, and also of the semi-compact type of *Perio* the number of genuine staminate flowers is very much less, while with the loose *Sholapuri* types there are hardly any of them. This is not due to the absence of pedicelled flowers because the *Sholapuri* types have almost as many of these as any, the lowest number being in the *Chapti jowar*. The proportion of pedicelled flowers to hermaphrodite flowers varies from 1·27 to 1 to 1·38 to 1.

It will also be noticed that between 59 and 68·5 per cent. of the flowers are arranged in pairs,—one flower of the pair being hermaphrodite and one pedicelled. The proportion does not vary very much from strain to strain. The remainder of the flowers almost all consist of groups of three, consisting of one hermaphrodite and two pedicelled flowers. Complete hermaphrodite flowers without any pedicelled flowers attached only occur in a limited number of cases, never exceeding 3·1 per cent and going down in certain cases (*Sholapuri* 21) to under 1 per cent. There is one other interesting feature which comes out from this analysis of the flower conditions in heads from a number of pure strains of *Kharif jowar* at Surat. This is as to the kind of flower group in which the genuine staminate flowers occur. The following figures show this :—

TABLE III.

Place of occurrence of staminate flowers.

	Pedicelled flowers per head	Staminate flowers per head	Hermaphrodite flowers with 1 staminate flower	HERMAPHRODITE FLOWERS WITH 2 PEDICELLED FLOWERS	
				(*a*) *Both* pedicelled flowers with *anthers*	(*b*) *one* pedicelled flower with *anthers*
Althan Deshi 6	3,242	1,291	544	85	577
Budh Perio 9	2,345	551	229	40	242
Mori Timberwa 7	1,894	367	189	17	144
Budh Perio 40	2,443	84	39	5	35
Chapti 8	1,506	13	none	none	13
Sholavuri 21.	2,261	4	2	none	2

It will be seen that in all the types except *Chapti* there is about an equal probability of genuine staminate flowers occurring in association with a hermaphrodite flower as a pair, and as *one* of two pedicelled flowers in association with a hermaphrodite flower in *Chapti* also. It is comparatively rare for both the pedicelled flowers in a group of three to contain anthers.

In this connection, it is interesting to observe that in all cases except in some measure in *Althan Deshi* 6 and *Budh Perio* 9, the upper portion of the earhead and the tops of each branchlet contain a larger proportion of genuine staminate flowers, particularly the double staminate ones than the rest. In the two types mentioned the distribution is fairly uniform.

TABLE IV.

Distribution of staminate flowers in earhead.

—	*Althan Deshi* 6	*Budh Perio* 9	*Moni Timberwa* 7	*Budh Perio* 40	*Chapti* 8
Proportion of staminate to pedicelled flowers in per centage—					
At the tops of panicle branches . .	44·7	50·6	55·1	64·3	100·0
In the upper one-third of panicle—					
(*a*) all flowers included . . .	17·4	24·5	41·4	58·3	84·6
(*b*) in groups with two pedicelled flowers	31·7	55·0	94·1	100·0	none
(*c*) in groups with one pedicelled flower	15·2	19·3	36·0	52·7	[84·6

The question thus arises as to the part which these staminate flowers play in the pollination and fertilization of the hermaphrodite flowers in the ear. To investigate this matter, a study of the progressive development of flowering on individual earheads was made.

Progressive development of flowering. The number of flowers opened each day was counted before any opening began in the following morning. The flowers in the earhead to open first are the hermaphrodite ones, and a few of these usually open before the earhead is completely out of the sheath (specially when grown on ridges or when the *Jowar* is drying up) and those at the top of the head are almost invariably the first to open.

The date at which the flowering started and the number of days needed for all male and hermaphrodite flowers on the same heads was recorded for a number earheads in 1922 and in 1926, with the following results :—

Variety and strain	Hermaphrodite flowers		Male flowers	
	Date of opening of first *flower*	Number of days to complete *flowering*	Date of opening of first *flower*	Number of days to complete *flowering*
Althan Deshi 6	..	..	..	..
1st earhead	Dec. 6, 1926	9	Dec. 9, 1926	9
2nd earhead	Nov. 23, 1926	11	Nov. 27, 1926	10
3rd earhead	Nov. 22, 1926	12	Nov. 25, 1926	13
Budh Perio 9	Nov. 16, 1922	11	..	..
Budh Perio 40	Dec. 7, 1926	9	Dec. 10, 1926	8
Chapti 8	Nov. 20, 1922	10	..	..
Sholapuri 1	Nov. 24, 1922	9	..	..

It will at once be seen that the hermaphrodite flowers commence opening in every case three or four days earlier than the male flowers. It also seems clear that the semi-compact or loose headed types like *Budh Perio* 40 and *Sholapuri* 1 complete the opening more rapidly than the others, even though the total number of flowers is equally great. In *Althan Deshi* 6, first earhead, the total number is small (669 hermaphrodite flowers as against over 1,000 in all other cases), the flowering still requires nine days to complete.

The progress of flowering from day to day was recorded for some of the above earheads, for both kinds of flowers, and the following table shows the result. The first day of flowering is in all cases the date of opening of a hermaphrodite flower.

TABLE V.

Progress of flowering in Jowar panicles I.

Days of flowering	VARIETY AND STRAIN							
	ALTHAN DESHI 6						BUDH PERIO 40	
	1st *earhead*		2nd *Earhead*		3rd *Earhead*		Herm. *flowers*	Male *flowers*
	Hermaphrodite *flowers*	Male *flowers*	Herm. *flowers*	Male *flowers*	Herm. *flowers*	Male *flowers*		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1st Day	9·7	..	0·3	..		..		..
2nd „	5·8	..	1·1	..		..		..
3rd „	8·8	..	5·4	..		..		..
4th „	31·1	1·9	31·9	..		1·5		5·0
5 „ „	13·2	6·7	13·1	..		9·2		10·0
6 „ „	15·4	12·5	14·9	14·8		8·2		32·6
7 „ „	2·8	10·9	20·8	32·9	not observed	19·1	not observed	29·5
8 „ „	7·8	25·7	5·5	26·9		16·6		8·2
9 „ „	5·4	28·1	3·9	16·3		9·2		6·5
10 „ „	..	3·1	1·5	3·6		13·6		3·2
11 „ „	..	6·9	1·6	3·6		11·6		5·0
12 „ „	..	3·9	..	contd. to 15th day.		10·8		..
13 „ „	..	..	..	..		6·8		..
14 „ „	..	..	..	..		1·4		..
15 „ „	..	..	..	..		0·6		..
16 „ „	..	..	..	..		0·2		..

We have similar records for the hermaphrodite flowers only with three other strains as follows :—

TABLE VI.

Progress of flowering (Hermaphrodite flowers only) in Jowar panicles II.

Days of flowering	Variety and Strain		
	Budh Perio 9	*Chapti 8*	*Sholapuri 1*
	Per cent.	Per cent.	Per cent.
1st day	0·2	0·2	1·5
2nd „	2·7	0·7	9·6
3rd „	6·4	3·2	17·0
4th „	13·3	12·5	23·8
5 „ „	9·1	24·1	23·5
6 „ „	24·2	25·1	14·7
7 „ „	18·6	17·3	7·0
8 „ „	10·4	12·9	2·6
9 „ „	9·9	3·7	0·2
10 „ „	4·7	0·2	..
11 „ „	0·3	..	..

It is clear, therefore, that in all cases examined the period of most active opening of the male flowers is three or four days later than that of the complete flowers, and they, likewise, complete their opening three or four days later.

Progressive development of complete flowers in different parts of earhead. In the year 1922-23 it was noted that the first complete flowers to open in all the Surat varieties were those at the top of the earhead, and that flowering progresses downward, stage by stage, the flowers on branches belonging to one whorl being usually in about the same stage of blooming. As a rule, flowers at the top of the inflorescence have shed their pollen and closed when the lower flowers of the head are just beginning to bloom.

If an earhead be divided into three portions—upper, middle, and basal—then the complete flowers in the middle portion start about two or three days later than those in the upper part, and those in the basal section one to two days later than those in the middle. The rapidity, or intensity of flowering is greater in the middle than in

either of the other two sections, as the following figures show, starting in each case from the date of commencement of flowering in that section. At such intense flowering periods the pollen from male flowers of the same earhead is available.

TABLE VII.

Progress of flowering (Complete flowers) in different parts of earhead.

——	Top of earhead	Middle of earhead	Base of earhead
Total number of complete flowers opened .	549	882	569
Percentage of flowers on each day—			
1st day	12·6	29·2	10·9
2nd „	9·8	32·3	34·3
3rd „	22·5	19·8	22·5
4th „	41·2	15·7	10·8
5 „ „	6·1	1·9	11·3
6 „ „	6·2	1·1	10·2
7 „ „	1·6	..	..

Progressive development of complete and male flowers as affected by exposure. At this stage the very interesting question arose as to how far the rapidity of opening of flowers was affected by exposure to full light and air. One side of each of two earheads (*Atthan Deshi* 6) which were naturally partly shaded and the course of flower opening was watched. The difference in the progress of the flowering in different parts of the earhead is shown below; starting in each case from the commencement of flowering in that section.

TABLE VIII.

Effect of exposure in progress of flowering.

	I. COMPLETE FLOWERS						II. MALE FLOWERS					
	Top of *earhead*		Middle of *earhead*		Base of *earhead*		Top of *earhed*		Middle of *earhead*		Base of *earhead*	
	E.*	P.†	E.	P.	E.	P.	E.	P.	E.	P.	E.	P.
Percentage of flowers opened on each day—												
1st Day	10·7	15·7	32·3	25·4	9·1	12·5	4·2	4·1	7·3	5·8	1·2	6·6
2nd ,, ...	9·0	10·7	33·2	31·2	35·7	33·1	19·3	16·6	10·5	8·8	9·1	9·3
3rd ,, ...	24·4	19·1	16·2	24·6	24·3	20·8	17·9	35·8	43·3	33·7	48·1	44·8
4th ,, ...	42·4	39·2	14·8	16·6	7·5	13·6	24·2	23·3	31·6	38·9	10·4	3·8
5th ,, ...	4·5	9·2	2·2	1·6	11·7	11·1	14·0	20·2	4·4	4·6	20·8	18·6
6th ,, ...	7·5	4·3	1·3	0·6	11·7	8·9	0·4	..	2·9	8·2	10·4	16·9
7th ,, ...	1·5	1·8	..	..	..	..	..	..	..	..	..	..

* E. Exposed flowers. † P. Partly shaded.

The effect of complete or under exposure of the earhead seems therefore not to affect materially the progress of flowering in a single head so far as the number of days is concerned, but the time of day at which flowers open is a little later in the exposed parts of heads.

Development of the essential sex organs of complete flowers. The essential organs of the complete flowers in *Jowar* are enclosed by two glumes. The outer glume is broad and somewhat loose ; the inner glume is narrower and much more firm. At the time of flower opening, the outer glume widens, and the inner one becomes looser. Then the stigma appears in all the Surat *Jowars* and sometime later one anther, and then again, still later, the other two (though not always simultaneously) protrude. The length of time the stigma appears before the anthers varies with different strains, but in two strains in 1926, they came out fifteen to twenty hours before the anthers. All the anthers appear, usually, within fifteen minutes from the coming out of the first anther.

The method of opening just described, which prevails in all the Surat varieties of *Jowar*, is quite different from that which takes place in Egyptian varieties of *Sorghum*, (Kaidi and Brown Yolo) when grown at Surat. In these latter, the anthers first appear, and then the stigma comes out later.

As has already been stated, shaded or protected flowers tend to open earlier in the morning of each day during the flowering period than do those which are fully exposed. The reason for this is not clear, and it does not agree with the general assumption in the case.

When it is cloudy the opening of flowers begins very early in the morning. Thus late in November in 1922, when the day maximum temperature was 80° to 93°F., and the minimum temperature was 68° to 70°F., the opening of flowers began at 4 a.m. and was practically finished by 6-30 a. m. On the chilly nights a few days earlier (minimum temperature 56 °F.) the greater number of flowers opened between 8-30 to 10-30 a.m. The flowers generally begin to close after 10-30 a.m., and there is practically no further opening till next day. In 1926, similar observations were made, but when the atmosphere was on the whole more moist, no opening of flowers was noticed before 7 a. m., and it continued till 10-30 a.m.

During the same season it was also noticed that on the same day the flowers in the upper part of the earhead open earlier in the morning than those in the middle, and these latter earlier than those near the base of the inflorescence. The differences are indicated in the following examples when the time of the beginning of opening is that of the *emergence of anthers* after the widening of the glumes. The strain used for these observations was *Althan Deshi* 6.

Date	Time of opening		
	Top of *earhead*	Middle of *earhead*	Base of *earhead*
I. Complete flowers	a. m.	a. m.	a. m.
Dec. 9, 1926	9-10	9-23	9-23
Dec. 10, 1926	9-0	9-30	9-36
Dec. 11, 1926	..	9-23	9-23
Dec. 12, 1926	..	8-0	10-0
Dec. 13, 1926	..	8-0	9-46
II. Male flowers.			
Dec. 12, 1926	9-24	9-30	10-0
Dec. 13, 1926	9-28	9-57	9-42
Dec. 14, 1926	9-0	9-34	9-38

As the season advances, the opening of flowers tends to commence earlier in the morning.

The pollen of Surat jowars. A study was conducted of the germination of pollen of complete flowers of the *Jowar* strain *Althan Deshi* 6, and also of staminate flowers of both *Althan Deshi* 6 and *Dhorio* from Kathiawar. The germination was tried with (1) pure distilled water, (2) 5 per cent. glucose solution, (3) 10 per cent. glucose solution, and (4) 15 per cent. glucose solution. Both fresh and stale pollen were used for the test.

With fresh pollen from complete flowers, germination in distilled water took place after 40 minutes; in 5 per cent. glucose solution after 30 minutes; in 10 per cent. glucose solution after 25 minutes; and in 15 per cent. glucose solution in the few cases where germination took place at all, in about 15 minutes. In this last case, however, the pollen burst after a few minutes. In any case, the germ tube is completely extruded after five to ten minutes.

With stale pollen from complete flowers the germination is a little delayed. Pollen collected on one morning is capable of germination for at least thirty hours, and cross-pollination was successful, after this time, with *Dhorio* pollen on *Althan Deshi* 6 flowers.

With fresh pollen from staminate flowers, germination was obtained in all the media mentioned above. But the pollen grains were found to germinate better and more rapidly than those from complete flowers in the more dilute solutions. Thus 5 per cent. glucose gave better results than 10 per cent. glucose. To some extent

the contents of the pollen placed in 15 per cent. glucose solution became contorted and they failed to germinate. Successful crosses were made with *Dhorio* pollen from staminate flowers on the stigma of *Althan Deshi* 6.

As the pollen from staminate flower germinates more rapidly and better in the more dilute solutions than that from complete flowers, it is very likely that this pollen may be playing a great part in natural pollination.

The Jowar earhead. The general character of the *Jowar* inflorescence has been already described (page 7). But a few more details regarding the earhead as found at the time of grain ripening may now be given. In any case, the head at flowering usually appears more loose than when ripening.

The earhead branches in the Surat *Jowars* are almost invariably short at the base, and those a little above this and at the middle of the earhead are generally the longest, giving very much an oval appearance to the heads.

The length of the peduncle is characteristic of certain varieties, as well as the shape of the head. In *Sholapuri* and *Nialo* types it is long.

In compact headed types at Surat the rachis is always short; in loose headed types it is always long.

The characteristics of earheads of different types, taken for four years, are shown below:—

TABLE IX.

Characteristics of Surat jowar earheads.

Name of strain	AVERAGE LENGTH OF RACHIS		AVERAGE NO. OF BRANCHES PER UNIT LENGTH OF RACHIS.		AVERAGE NO. OF SEEDS PER BRANCH		AVERAGE WEIGHT OF 1,000 SEEDS IN GRM.	
	1923-24 to 1925-26	1925-26 to 1926-27	1923-24 to 1925-26	1925-26 to 1926-27	1923-24 to 1925-26	1925-26 to 1926-27	1923-24 to 1925-26	1925-26 to 1926-27
	cm.	cm.	*Compact.*				grm.	grm.
Althan Deshi 6	8·09	8·70	91·6	93·2	24·3	27·45	36·95	41·2
Budh Perio 7	9·69	9·75	95·4	106·6	19·5	21·8	36·59	38·35
Moti Timberua 7	8·95	9·05	87·1	92·5	21·0	23·35	38·84	41·55
	Semi-Compact.							
Budh Perio 53	..	11·35	..	99·05	..	21·30	..	44·55
Chapti 8	8·12	8·05	74·6	77·65	22·7	21·35	47·39	47·0
Telia Chapti 24	..	10·45	..	72·3	..	27·55	47·8	40·40
Telia Chapti 26	..	10·85	..	81·7	..	23·05	47·1	39·45
	Loose.							
Sholapuri 18	..	15·4	..	50·6	..	25·2	..	39·75

The statement that a short rachis is characteristic of compact types is generally true, except with *Chapti* 8, which though only possessing a semi-compact earhead has the shortest rachis length. The character of the head is still more determined by the number of branches per unit length (10 cm.) of the rachis. The greater the number of branches per unit length, the more compact the head. The heaviest seeds, *i.e.*, biggest ones, are generally found in semi-compact types. Minor differences noticed are :—

(1) A peculiar narrowing down of the head just below the tip. This is generally found in blunt compact types, but in some it is very obvious as in *Budh Perio* 7. It is due to shorter length of the branches of the two or three whorls below the last, and relatively longer branches of the last whorl at the tip.

(2) A pitted appearance of the earhead at the tip. This is found in *Althan Deshi* 6, and *Budh Perio* 7, both compact types.

(3) A blunt or tapering tip to the earhead. A tapering earhead is generally found in loose headed types, and to a small extent in semi-compact types. It seems due to longer or fewer branches in the last few whorls near the tip. All *Sholapuri* types have a tapering earhead. The types *Budh Perio* 40 and *Chapti* 8 tend in the same direction. A blunt tip is rather characteristic of compact headed types.

(4) A bulge in the earhead, slightly above the base or in the middle. This is due to a sudden reduction in the distance between whorls in the rachis or to the greatest length of one or two branches of a whorl. The appearance is quite characteristic of *Althan Deshi* 6 and *Budh Perio* 53.

(5) A cylindrical appearance of the earhead. This is seen, for example, in *Budh Perio* 40, and appears due to the uniform length of branches in most of the whorls.

Natural Cross Fertilization in Jowar at Surat.

All the characteristics of the inflorescence and of the individual flowers in *jowars* would suggest that cross-pollination would be frequent. The chances of such cross-pollination would seem to depend on the following factors :—

1. *The time of extrusion of the anthers and stigma.* It has been shown that in many cases such as *Budh Perio* 7 the stigma may be protruded for twenty hours before the anthers of the same flower give pollen. In one case particularly noted with the strain mentioned, the stigma appeared at 5-30 p.m. on December 14th, 1926 ; at 6-30 a.m. on December 15th the stigma had not been pollinated nor were the anthers dehisced ; at 8-30 a.m. in this day, pollination had occurred and the anthers dehisced. It is necessary, therefore, to revise the conclusion reached in

1907-09 by workers at Surat[1] that cross-fertilization was unlikely in *jowars* at Surat. This was confessedly based on experience with Egyptian *jowars*, and it is now clear that the relative time of appearance of the male and female organs varies much with different varieties and strains of *jowar*.

2. *The extent of extrusion of the anthers.* In a number of flowers on an earhead, the anthers fail to appear at all, or only are very partially extruded. In these cases the chances of cross-pollination are many. In the strain *Althan Deshi* 6 both these conditions occurred.

3. *The pollen available when the stigmas are receptive.* The anthers dehisce in most Surat varieties some time after the stigma is exposed, so that the chance of pollination from another flower is very great. There are, moreover, a very much large number of staminate than of hermaphrodite flowers, and the pollen from such staminate flowers germinates more quickly and in weaker solutions than that from the complete flowers. The male flowers start opening and finish opening a little later than the complete flower.

Though all these considerations make a large proportion of cross-fertilization likely, yet how far it does actually occur can only be determined by a direct experiment. Such an experiment was made in two succeeding years, and the method adopted was to take plants which had bred true to certain characters for at least two generations and expose them in alternate lines to plants in which these characters were different and were equally fixed. The characters chosen for testing the extent of cross-fertilization were as follows :—

1. Colour of midrib of leaf—white or greenish.
2. Anther colour, after weathering,—yellow, red or brown.
3. Earhead texture—compact, semi-compact or loose.
4. Grain colour—white, whitish yellow or yellowish.
5. Glume character—the extent to which the seeds are covered.

With regard to some of these characters, observations of importance have previously been made. It may be noted that the colour of the midrib is important, as it seems to be correlated with the sweet or pithy character of the stem.[2] Hilson, working in Madras, has observed that a white midrib means a pithy stem when the plant is in shot blade and for some time after. Further he has noted that in breeding tests the pithy character of the stem, and hence the white midrib, behaves as a simple dominant to the sweet stemmed character and hence to the green midrib.

In connection with the question of anther colour, [3] Graham, working at Nagpur, has noted that in his experience the colour of the grain can be judged at the time of flowering, the stamens and stigmas of plants giving red grains being orange in colour

[1] *Annual Report, Bombay Department of Agriculture*, 1907-08, page 17 : 1908-09, page 20.
[2] *Agri. Journ. India*, Vol. XI, p. 154.
[3] *Mem. Dept. Agri., India, (Bot. Ser.)*, VIII, No. 4.

and the colour in the case of types with white or yellowish grain being pale yellow. This observation, it may be noted, does not apply entirely to the *jowar* at Surat, for there exist both yellow and red anthered types with white and yellowish grain.

As regards the question of colour of grain and texture of earheads, observations have been made by Kottur and Kulkarni[1] working at Dharwar and they have used them as a means of testing the amount of cross-fertilization. Judged by the presence of earheads of intermediate texture and brown grain colour, in the progeny of single selected earheads placed at different distances in the field, they have stated that contamination from a variety grown round the border of a field varies from nothing up to 12 per cent. according to the distance from the border.

Other observations on the extent of cross-fertilization have been made by C. R. Ball[2], in America, who states that contamination between adjacent rows may be anything up to 50 per cent. Graham's figure (*loc. cit*) varies from 0·6 to 20 per cent. Naturally, the figure would vary according to the position, the nature of the variety from which contamination takes place, the distance from the source of contamination, and the prevailing environmental conditions.

Now, in the first place, it was desired to ascertain with regard to the midrib and anther character above referred to, as to what is the extent to which plants with these characters can be relied on to breed true when the parent earhead has been bagged and so self-fertilization secured, or when an ordinary unbagged earhead is taken from the field.

Midrib character. In 1922-23, it was found that the seed obtained from unbagged earheads on green-ribbed plants in selections of *Sholapuri Jowar* bred true, while those from the white-ribbed plants were variable in this respect. In certain cases they bred true ; in others they gave a ratio of white-ribbed to green-ribbed plants in the progeny of 5·3 or 5·4 to 1.

In 1924-25, in a selection from *Chapti jowar* in culture made with seed from bagged heads, all the plants from a green-ribbed parent bred true to this character and this is not in one but in several selections. In the case of selection 48 (from a white-ribbed parent) two out of three cultures bred true ; the third gave a ratio of white to green-ribbed plants of 2 to 1.

Anther character. In 1923-24, it was found that the seed obtained from mother earheads with red anthers either gave entirely flowers likewise with red anthers or flowers with red and yellow anthers in various proportions from 2·9 to 5·3 to 1. Where the mother plant had yellow anthers, however, the progeny bred true in this respect. This latter fact was also the case in a series of cultures made in 1924-25, when again red or brown anthered mother plants gave very variable results, red or brown anthers being 1·7 to 4·1 times more numerous than yellow anthers in the progeny.

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[1] *Agri. Journ. India*, Vol. XVII, p. 413.
[2] C. R. Ball, *American Breeder's Assn.*, Vol. VI, p. 103.

We have thus a clear method of determining the extent of cross-fertilization by observing these characters. If seeds from strains are taken which have a green midrib and yellow anthers, the progeny will breed true to these characters unless it has been crossed with a strain with white midribs to the leaves or with red or brown anthers.

Such strains were, therefore, selected for the experiment in 1923-24, the ones chosen being *Budh Perio* 9 and *Sholapuri* 1. The characteristics of each are shown in the following Table :—

Character	*Budh Perio* 9	*Sholapuri* 1
Midrib of leaves	green	white.
Anther colour	yellow	red.
Earhead texture	compact	loose.
Grain colour	yellowish	whitish.

The strains used represented the progeny of selfed earheads and were pure as to the characters considered. The flowering time was practically identical. Two rows of *Budh Perio* 9 were planted immediately to the south of several rows of *Sholapuri* 1 and the seed from each row of the former was preserved and sown. The distance between the rows was three feet, so that the first row was three feet and the second row was six feet to the south of the first line of *Sholapuri jowar*.

The result was observed in the crop of 1924-25, taking the progeny of six different plants selected at regular distance from each row and the amount of crossing judged by the number of plants with white midribs to the leaves and red or brown anther colour. The results are shown in the following Table :—

No. of plant	No. of plants with characters of mother	No. of plants with white midribs, red anthers, semi-compact earhead	Percentage of crossed plants
I. Row of *Budh Perio* 9, three feet distance from *Sholapuri* 1.			
1	53	15	22·0
2	66	22	25·0
3	84	13	13·4
4	64	24	27·3
5	74	15*	16·8
6	52	43	45·3
Total average	393	132	25·0

* One of these plants had green midrib, red anthers, and semi-compact head.

No. of plant	No. of plants with characters of mother	No. of plants with white midribs, red anthers, semi-compact earhead	Percentage of crossed plants
II. Row of *Budh Perio* 9, six feet distance from *Sholapuri* 1.			
1	72	7	8·9
2	72	7	8·9
3	60	28	31·3
4	59	29	33·0
5	50	31*	38·3
6	64	26†	29·0
Total average	377	128	25·0

* Five of these plants had green midribs, red anthers, and semi-compact heads.
† One of these plants had green midrib, red anthers and semi-compact heads.

The naturally crossed plants had their leaves with white midrib and earheads with brown anthers, the head being of a semi-compact character.[1] The anther colour was not truly red and appeared to be intermediate between that of the parents.

The extent of cross-fertilization varies from 13 per cent. to 45 per cent. in the nearer row, and from 9 per cent. to 38 per cent. in the second row from the *Sholapuri* 1 type. Not a single one of the heads used as representatives,—taken fairly equidistant along the rows—had been unaffected by the nearness of the contaminating type. It is curious to find that the average amount of crossing is the same in the second as in the first row (though the maximum and minimum are lower in the second row) and it suggests that some other influence than that of the wind is at work,—probably insects.

Such were the results obtained in 1923-24. In the following year, at Surat, a similarly arranged experiment was conducted with the strain *Chapti* 8, again using *Sholapuri* 1 as the means of contamination. The distances of rows of *Chapti* 8 from the contaminating row of *Sholapuri* 1 varied from three feet to thirty-six feet, and the amount of crossing was as follows :—

Distance from row of *Sholapuri* 1.	Percentage of crossing
3 feet	5·2
6 and 9 „	0·5
12 and 15 „	1·5
18 and 21 „	2·1
24 and 27 „	2·6
30 and 33 „	0·5
36 „	2·0

[1] One of the Madras workers has stated the open head character is dominant over the compact head. *Journal of Madras Agricultural Students' Union*, Vol. XII, No. 1 (1924).

It is clear that in 1924-25 the amount of crossing was far less than in the previous year, and that it was not proportionate to distance.

An inspection of a crop raised from unselfed heads of the strains *Althan Deshi* 6 and *Moni Timberwa* 7 in the same year, gave a crossing percentage of 2·2 per cent. and 2·3 per cent. in two cases.

In summary, it would now seem certain that extensive crossing does take place under natural conditions between different strains of *Jowar* at Surat, which may go up to between 40 and 50 per cent. It varies, however, very much from season to season. As the amount does not vary with the distance of the contaminating agent, it seems probable that other agencies than that of the wind are at work,—probably insects, and we may, so far as Surat is concerned, decide that the conclusion reached in 1908-09 that natural cross-fertilization does not take place in *Jowar*[1] is not correct.

The hereditary nature of certain characters in Surat jowars.

From the description of the three main varieties of Surat *jowar* (page 3), it will be seen that what goes under the name of a variety,—whether it be *Perio*, *Chapti* or *Sholapuri*,—is really a series of strains, most of which possess certain varietal features, but which differ from one another by important botanical and economical characters. These strains are, however, not merely mixed, but have crossed and recrossed with one another to an enormous extent, and few, if any, of a pure character now exist in the whole district. Any attempt to improve the character of the *jowar* grown, or even to fix standard types, must be commenced by the development of strains breeding true. For this purpose, therefore, original selections from *jowars* of each variety growing in the field were made in 1922-23 and subsequent generations of these selections have been grown from seed obtained from self-fertilized covered heads since 1923-24. Crops have always been grown by dibbling seed eighteen inches apart in rows three feet from one another.

Apart from the primary object of the work, namely, to develop fixed strains of special economic value, the selections have been studied in order to find out (1) what characters show constancy and similar differences from strain to strain in a series of years, and which are thus of a hereditary nature and can be fixed by breeding, (2) what is the normal variability of such hereditary and also of other characters from season to season, (3) whether there are any other characters normally associated with a high yield of grain, so that these may be produced in any possible way. During the study, many selections which neither possessed economic value themselves nor which showed characters which would be useful in crossing were abandoned,—but even these have given results of importance to the present study.

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[1] *Annual Report, Department of Agriculture, Bombay*, 1908-09, page 21.

The characters which have been studied in the manner described are as follows :—

A. The leaf area per plant.
B. The hairiness and colour of the leaves.
C. The height of the plant.
D. The thickness of the stem.
E. The number of nodes on the stem.
F. The colour of the shrivelled anthers.
G. The number of days from germination to flowering.
H. The length of the rachis.
I. The number of branches on the rachis.
J. The characters of the seed, including size, plumpness, uniformity and colour and the weight of the seeds.

A. The leaf area per plant.

The leaf area per plant may be considered as the area of the leaf blades *plus* the area of the leaf sheaths. In 1923-24, all the leaves of sixty-five plants of selections from the *Perio*, *Chapti*, and *Sholapuri* varieties were measured. It was found that in 66·2 per cent. of cases, the fourth leaf from the top represented approximately the average size of all the leaves of the plants. In 19·7 per cent. of cases, the fifth leaf represented the average, and in 14·1 per cent. of cases, the third leaf was in this position. In succeeding years, the fourth leaf only was measured and was taken as representing the average, and its area multiplied by the number of leaves per plant was taken to represent the leaf area of the plant.

The area of the fourth leaf was determined by treating the blade and the sheath separately as follows :—

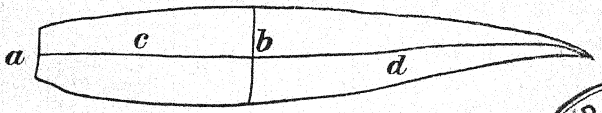


Fig 1.

In the blade, four measurements were made, namely—

1. (*a*) The width at the base.
2. (*b*) the width at the maximum breadth.
3. (*c*) the total length of the blade.
4. (*d*) the length from the point of greatest breadth to the tip.

The blade area was then approximately obtained as follows :—

$$\frac{a+b}{2}(c-d)+\frac{1}{2}b \times d.$$

The sheath area of the whole plant was considered as a cylinder whose length was the height of the plant up to the flag, and whose diameter was that of the middle internode of the plant at the midpoint.

There are thus three main factors determining the leaf area, namely the total length of leaf, the maximum breadth of leaf, and the number of nodes or leaves.

Since 1925-26, the lamina area has been obtained from the fourth leaf by Amsler's Plenimeter.

In studying the results, it will be well to take the lamina or blade area of the fourth leaf first. The criterion used in this as in all other cases for determining how far a character is hereditary is to see how far *relative* differences persist from year to year when conditions of cultivation are similar in different strains. In the present case, the figures for 1926-27 are not quite comparable with the others, as owing to a bad attack of borer and to irregularity caused by heavy excessive rains, the planting was not quite regular. The results with four strains are given, however, for four years, and for others for two years.

TABLE X.

Blade area of fourth leaf of jowar strains.

Strain	BLADE AREA IN SQUARE CENTIMETERS				
	1923-24	1924-25	1925-26	1926-27	Average of 1923-26
	sq. cm.	sq. cm.	sq. cm.	sq. cm.	sq. cm.
Athan Deshi 6	204	216	247	333	222
Budh Perio 7	233	221	285	326	246
Moni Timberwa 7	236	251	273	288	254
Chapti 8	244	221	220	277	228
Sholapuri 1	230	250	..	..	..
Budh Perio 40	162	154	..	..	..
Budh Perio 53	..	..	259	387	..
Telia Chapti 24	..	..	245	369	..
Telia Chapti 26	..	..	205	322	..
Sholapuri 18	..	..	223	322	..

The most that can be said from these figures is that certain strains have large leaves like *Moni Timberwa* 7, and others have small leaves like *Budh Perio* 40. In smaller differences, there seems little if any regularity.

If we now take similarly the whole leaf area of the plants in each year, the following figures are obtained.

TABLE XI.

Total leaf area per plant in jowar strains.

Strain	TOTAL LEAF AREA IN SQUARE CENTIMETERS				
	1923-24	1924-25	1925-26	1926-27	Average 1923-26
	sq. cm.	sq. cm.	sq. cm.	sq. cm.	sq. cm.
Althan Deshi 6	3,046	4,099	5,127	4,373	4,091
Budh Perio 7	3,609	4,166	5,929	4,099	4,568
Moni Timberwa 7	3,641	4,798	5,823	3,284	4,754
Chapti 8	3,905	4,147	4,270	3,346	4,107
Sholapuri 1	3,422	4,694	..	..	..
Budh Perio 40	2,386	2,931	..	..	..
Budh Perio 53	..	..	5,563	6,002	..
Telia Chapti 24	..	..	4,863	5,416	..
Telia Chapti 26	..	..	4,172	4,677	..
Sholapuri 18	..	..	4,764	4,372	..

From these figures it seems quite evident that the leaf area is only hereditary in the broadest sense. There are certainly strains with low leaf area like *Budh Perio* 40 and others with high leaf area in all the normal years tested, like *Budh Perio* 53 or *Moni Timberwa* 7. But apart from this broad difference, the order of leafiness among the plants varies very much from year to year, and is evidently determined more by the question of whether the environmental conditions of that particular season suits that particular strain or not.

But one association does appear to exist at least among the Surat types examined. The earliness or lateness of flowering seems constantly associated with the amount of leaf area per plant. An early plant has a small leaf area, and *vice versâ*. *Budh Perio* 40 which has the lowest leaf area is the earliest. Next stands *Althan Desh*

6 in both these respects. Similarly, the type with the largest leaf area.—*Moni Timberwa* 7 and *Budh Perio* 53 are the latest. It is not contended that this connection is generally true among types of *jowar*, but it certainly seems to apply among those cultivated in Surat.

Within each strain, the grain yield of each plant has been taken each year, along with the leaf area of each plant, and thus it is possible to determine whether there is any marked correlation between the leaf area and the yield of grain. The results are shown in the following table, where the co-efficient of correlation between these two factors is indicated :—

TABLE XII.

Correlation, within strains, between leaf area and grain yield.

Strain	Co-efficient of correlation of leaf area with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·90±0·02	0·73±0·03	0·85±0·02	0·58±0·04
Budh Perio 7	..	0·81±0·03	0·87±0·01	0·59±0·04
Moni Timberwa 7	..	0·85±0·02	0·86±0·02	0·72±0·04
Chapti 8	..	0·87±0·02	0·92±0·02	0·77±0·03
Budh Perio 53	..	..	0·82±0·02	0·49±0·04
Telia Chapti 24	..	..	0·89±0·02	0·81±0·02
Telia Chapti 26	..	..	0·83±0·02	0·75±0·03
Sholapuri 18	..	..	0·88±0·03	0·72±0·03

It will be seen that, within each strain, there is a very close relationship between the leaf area and the yield of grain, or in other words, any treatment which will increase the leaf area will also increase the yield of grain, whether this treatment be by cultural changes or manurial methods.

B. Hairiness and colour of the leaves.

At the ligules there is always a fringe of hairs, and this always extends on the midrib to about one inch from the base either on one side or on both. In all the varieties there are strains whose general hairiness on the leaf is very different.

Thus if the types isolated be classified according to hairiness, the following is the result :—

Perio types. Out of twenty types isolated, sixteen are hairy, two are sparsely hairy, and two are glabrous or very nearly so.

Chapti types. Out of ten types isolated, three are hairy, three are sparsely hairy, and four are glabrous or very nearly so.

Sholapuri types. Out of seven types isolated, four are hairy, two are sparsely hairy, and one is glabrous or very nearly so.

The *Chapti* types are on the whole the least hairy, while the large majority of the *Perio* and *Sholapuri* strains are hairy. The hairs drop off as soon as the leaves dry up.

The hairy character remains highly constant from generation to generation in each type.

Colour of the midrib. If we consider the colour of the midrib, it appears at once that we are in presence of a character which is constant and hereditary and that a white midrib is dominant over a green midrib. This character should be judged after two to two and half months' growth, and has in our experience always been constantly associated with the sweetness or pithiness of the stem. A white midrib to the leaves is, in fact, always associated with a pithy stem of inferior value as fodder and a green midrib to the leaves with a sweet stem of high fodder value.

Out of seventeen pure *Perio* types which have been isolated eleven (65 per cent.) had green midribs and six (35 per cent.) had white midribs. Both bred true to this character during several generations. Out of eight pure *Chapti* types, all had green midribs, and out of five *Sholapuri* strains isolated in a pure condition, two had green midribs (40 per cent.) and three had white midribs (60 per cent). All bred true to this character.

Colour of leaves. If examined after two to three months' growth, there are distinct differences of tint in the green colour. Thus *Althan Deshi* 4 *and* 6 and also *Budh Perio* 42 all have a very characteristic dark green colour of the foliage which marks them out, and enables them to be easily distinguished. It is constant for several generations.

Wax on the sheath of upper leaves. The waxiness of the sheath of the upper leaves varies considerably, but in certain cases it is very great, as in *Althan Deshi 6.* It is constant from generation to generation.

C. The Height of the plant.

The height of the plant has been in all cases measured from the flag, that is to say, the node on the stem from which the peduncle appears down to the first node in the soil. It varies, however, as would be expected, very markedly from season to season, and is largely affected by the number of nodes formed. Thus the reduced height in an unfavourable season due to a lesser number of nodes is only very slightly made up by increase in the length of the internodes.

Variation in height from year to year in a number of pure types is shown below:—

TABLE XIII.

Average height of plants in Surat jowars.

Strain	Height of plants in centimeters				
	1923-24	1924-25	1925-26	1926-27	Average of 1923-26
Athan Deshi 6	115	163	158	103	145
Budh Perio 7	145	171	178	104	165
Moni Pimberwa 7	126	165	156	81	149
Chapti 8	143	163	134	91	146
Sholapuri 1	127	179	..	..	..
Budh Perio 40	109	163	..	..	..
Budh Perio 53	..	..	154	129	..
Telia Chapti 24	..	..	122	115	..
Telia Chapti 26	..	..	138	122	..
Sholapuri 18	..	..	155	124	..

It cannot be stated that there is any constant relationship between the height of the various types of plant. They were nearly all tallest in 1924-25. The most that can be said is that certain strains are normally tall like *Budh Perio* 7 and others normally short (like *Chapti* 8). In smaller differences there seems little of any regularity.

Within each strain, the grain yield of each plant has been taken each year, along with the height of each plant. The results show a very marked correlation between the height and the yield of grain.

TABLE XIV.

Correlation, within strains, between height and grain yield.

Strain	Co-efficient of correlation of height with yield			
	1923-24	1924-25	1925-26	1926-27
Athan Deshi 6	0·83±0·03	0·69±0·04	0·75±0·03	0·54±0·05
Budh Perio 7	..	0·56±0·05	0·85±0·02	0·76±0·03
Moni Pimberwa 7	..	0·67±0·04	0·86±0·02	0·73±0·04
Chapti 8	..	0·76±0·03	0·90±0·02	0·64±0·05
Budh Perio 53	..	..	0·82±0·02	0·52±0·05
Telia Chapti 24	..	..	0·86±0·02	0·67±0·04
Telia Chapti 26	..	..	0·83±0·02	0·59±0·04
Sholapuri 18	..	..	0·89±0·02	0·48±0·05

The correlation is highest in a dry year as 1925-26, while the lowest is in 1926-27, when the percentage of stand of plants was very poor. Thus, even in a dry year, a tall plant in a field is likely to yield more grain.

D. The thickness of the stem.

The thickness of the stem was taken by measuring the circumference by means of a graduated strip of paper, at the middle of an internode. The internode taken has been always the middle one. Thus, if there are eleven nodes, it will be the sixth, if there are ten or twelve, two measurements are taken one on each of the two middle nodes.

The results are tabulated below :—

TABLE XV.

Circumference of stem of Surat jowars.

Strain	Circumference in millimeters				
	1923-24	1924-25	1925-26	1926-27	Average of 1923-26
	mm.	mm.	mm.	mm.	mm.
Althan Deshi 6	32·5	38·1	42·4	50·9	37·7
Budh Perio 7	38·8	38·9	44·9	50·3	40·9
Moni Timberwa 7	36·2	41·1	44·3	46·0	40·5
Chapti 8	38·2	38·3	37·4	43·0	38·0
Sholapuri 1	35·0	39·4	39·7	..	38·0
Budh Perio 40	30·5	32·5	..	..	..
Budh Perio 53	..	..	44·0	60·	..
Telia Chapti 24	..	..	41·4	54·8	..
Telia Chapti 26	..	..	39·1	51·5	..
Sholapuri 18.	..	..	43·2	49·7	..

There is at least a suggestion in these figures that among the Surat *jowars* a thin stemmed type is likely to be an early one, and a thick stemmed type a late

one. Thus *Budh Perio* 40 has the thinnest stem, and is earliest in flowering. *Budh Perio* 53 is the thickest stemmed strain, and is the latest in flowering.

Within each strain the plants with the thickest stem have generally given the highest yield, and the correlation between thickness of stem and the yield has proved to be high. The following Table shows the co-efficient of correlation of these factors in three successive years :—

TABLE XVI.

Correlation, within strains, between stem thickness and grain yield.

Strain	Co-efficient of correlation of stem thickness with yield		
	1924-25	1925-26	1926-27
Alhan Dedhi 6	0·80±0·03	0·92±0·01	0·65±0·04
Budh Perio 7	0·78±0·03	0·91±0·01	0·52±0·05
Moni Timberwa 7	0·91±0·01	0·93±0·01	0·72±0·04
Chapti 8	0·88±0·01	0·98±0·01	0·73±0·04
Budh Perio 53	..	0·93±0·01	0·52±0·05
Telia Chapti 24	..	0·85±0·02	0·76±0·02
Telia Chapti 26	..	0·88±0·01	0·54±0·04
Sholapuri 18	..	0·92±0·02	0·80±0·02
Sholapuri 1	0·87±0·02	..	..

E. The number of nodes in the stem.

The number of nodes in the stem varies from year to year, but there is little relationship between the number of internodes and the height of the plants. Though in 1926-27 the number of nodes was the least in our series of years, and the height of the plants was likewise the least, yet in 1925-26 when the number of nodes was the greatest in the series, the height was not the greatest owing to adverse conditions of drought in the latter part of the season.

The following Tables show the number of nodes in a series of years in strains of Surat *jowars*, and the average length of internode in each strain :—

TABLE XVII.

The number of nodes in stems of Surat jowars.

Strain	Average number of nodes			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	13	16	18	13
Budh Perio 7	13	16	18	11
Moni Timberwa 7	13·5	16·5	18	10
Chapti 8	14	16	16·5	10·5
Budh Perio 53	..	..	18·5	13·5
Telia Chapti 24	..	..	17·5	13
Telia Chapti 26	..	..	18	12·5
Budh Perio 40	12·5	15·5	..	..
Sholapuri 1	13·0	16	..	..
Sholapuri 18	..	..	18	11·5

TABLE XVIII.

Length of internodes in stems of Surat jowars.

Strain	Average length of internode			
	1923-24	1924-25	1925-26	1926-27
	cm.	cm.	cm.	cm.
Althan Deshi 6	9·6	10·8	9·3	8·6
Budh Perio 7	12·1	11·5	10·6	10·4
Moni Timberwa 7	10·1	10·7	10·6	9·0
Chapti 8	11·2	10·9	8·6	9·3
Budh Perio 53	..	..	8·7	10·4
Telia Chapti 24	..	..	7·4	9·7
Talia Chapti 26	..	..	8·2	10·5
Budh Perio 40	9·4	11·2	..	..
Sholapuri 1	10·6	11·9	..	..
Sholapuri 18	..	..	8·5	11·7

The average length of internodes seems to be little, if any, guide to the character of a strain, and seems pre-eminently to be the character of the season in which the *jowar* is being grown. The length of the internodes, even in a particular part of the season, seems to reflect the vigorous or poor growth at that part of the season.

Thus in 1925-26, a year of drought in the latter part of the season, the upper internodes were very short. But with all this, there are characteristic differences of the strains in extreme cases only, which persist throughout. Thus the *upper* internodes were always shorter in the case of *Althan Deshi* 6 than in any other of the strains in hand, while in *Sholapuri* 18 they were always the longest.

Within a strain, the number of nodes seems to have some relationship to the yield of grain, though the correlation is not very constant or very close. In 1926-27, when as has already been stated the conditions of growth were abnormal, it almost disappears. In other cases, a large number of nodes seems to indicate a vigorous, and hence a high yielding plant.

TABLE XIX.

Correlation, within strains, between number of nodes in the stem and grain yield.

Strain	Co-efficient of correlation of number of nodes with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·74±0·04	0·79±0·03	0·74±0·04	0·24±0·06
Budh Perio 7	..	0·68±0·04	0·87±0·02	0·23±0·06
Moni Timberwa 7	..	0·83±0·02	0·86±0·02	0·35±0·07
Chapti 8	..	0·82±0·02	0·87±0·02	0·24±0·08
Budh Perio 53	..	..	0·81±0·03	0·20±0·06
Telia Chapti 24	..	..	0·66±0·04	0·30±0·06
Telia Chapti 26	..	..	0·73±0·03	0·27±0·06

F. The colour of the shrivelled anthers.

The colour of the shrivelled anthers seems an absolutely constant character from generation to generation and hence has great value in roguing out forms which are not true to type.

The anther character has been discussed in detail in connection with the study of the natural cross-fertilization of *jowar*, and it was found that a yellow colour in these organs was completely recessive, the red or brown colour being dominant.

Each of the current varieties is mixed in the matter of anther colour, for strains with yellow anthers can be found among *Perio, Chapti* and *Sholapuri* types, strains with brown anthers have been detected among both *Perio* and *Sholapuri* types, while strains with red anthers are found in all the three series of types.

G. The period from germination to flowering.

The length of the time between germination and flowering is, on the whole, a very constant character, that is to say, the relationship as to earliness between different strains is maintained in seasons of very different characters, and within the strain the plants differ very little in this feature. It must be made clear, however, that an early flowering type is not *necessarily* an early ripening type. Our study indicates that though a type may be late in flowering yet it may ripen almost at the same time as one which flowered much earlier. This is important, because the need is felt for types which can be sown late, and yet can be relied upon to mature the grain fully, and the introduction of varieties like *Sholapuri* and *Khaplatio-Niulo* is largely due to their advantage in this respect.

The average flowering period has been worked out, in connection with the figures which follow, by counting the number of days from the general date of germination to the flowering of a number of individuals, and then taking the average of the figures so obtained. The actual figures for ten strains of *jowar* and for the local mixed *Perio* variety at Surat are shown in the following Table. The figures for 1926-27 are not entirely comparable as the stand of plants in that year was very irregular owing to excessive rain and to borer attack.

TABLE XX.

Period from germination to flowering in Surat jowars.

Strain	Average number of days from germination to flowering				
	1923-24	1924-25	1925-26	1926-27	Average 1923-26
Athan Deshi 6	114	100	101·5	125	105·3
Budh Perio 7	115	104·5	107·5	141·5	109
Moni Timberwa 7	118	105·5	111	144	111·3
Chapti 8	116	104·5	111	145·5	110·5
Sholapuri 1	121	105	107	..	111
Budh Perio 40	112	92·5	98	..	100·8
Budh Perio 53	..	..	119	137·5	..
Telia Chapti 24	..	..	120	145	..
Telia Chapti 26	..	..	120·5	145·5	..
Sholapuri 18.	..	..	116·5	145·5	..
Local *Perio Jowar* at Surat Farm	123	..	119	136	..

These figures clearly indicate that the order is very closely maintained in the first three years, which alone are comparable, for the reasons already given, and that thus the character is definitely a hereditary one. *Sholapuri* types, when grown under identical conditions, are not earlier than the *Perio* types. They will, however, flower normally if planted late which many of the *Perio* types fail to do.

The plants within a strain show that there is a distinct *negative* correlation of earliness with high yield though the extent of the correlation varies much from year to year and in 1926-27 disappears in some cases, possibly owing to the irregular and unusual conditions of cultivation in that year.

TABLE XXI.

Correlation, within strains, between early flowering and grain yield.

Strain	CO-EFFICIENT OF CORRELATION OF EARLY FLOWERING WITH YIELD			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·64±0·06	0·59±0·05	0·60±0·04	0·28±0·06
Budh Perio 7	..	0·40±0·07	0·22±0·06	0·18±0·06
Moni Timberwa 7	..	0·52±0·05	0·33±0·06	0·32±0·08
Chapti 8	..	0·71±0·03	0·60±0·01	0·45±0·05
Sholapuri 1	..	0·25±0·07	..	..
Budh Perio 53	..	..	..	0·36±0·06
Telia Chapti 24	..	..	0·31±0·01	0·41±0·05
Telia Chapti 26	..	..	0·31±0·06	0·59±0·05
Sholapuri 18	..	..	0·18±0·01	0·24±0·06

H. The length of the rachis.

The earhead characters as a whole are, as would be expected, very much more constant than the vegetative ones. The length of the rachis, which determines very largely the general appearance of the earheads, varies, in fact, very little from season to season and would be expected to be definitely hereditary. It has been measured from the scar of the lowest branch to the tip from which a large number of

branches arise. The actual results of such measurements are shown in the following Table :—

TABLE XXII.

Length of rachis in Surat jowars.

Strain	Average length of rachis in centimeters			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	7·9	8·1	8·3	9·1
Budh Perio 7	..	9·2	10·2	9·5
Moni Timberwa 7	8·8	8·9	9·2	8·9
Chapti 8	..	7·7	7·7	8·4
Sholapuri 1	14·2	13·6	..	..
Budh Perio 53	..	..	11·2	11·5
Telia Chapti 24	..	..	10·3	10·6
Telia Chapti 26	..	..	11·2	10·5
Sholapuri 18	..	..	15·7	15·1
Local *Perio Jowar* at Surat Farm	9·0	..	9·3	10·3

The relation between the different strains is almost similar throughout. In 1926-27 there is an exception in the case of *Althan Deshi* 6 and *Moni Timberwa* 7, but the differences in spacing that year deprive this result of much value. The general agreement, however, makes it certain that we are in face of a genuine hereditary character only modified to a limited extent by environmental conditions.

Within the strain, the longer rachis gives the higher yield, and there is, as would be expected, usually a high correlation between these two. Selection for high yield by picking the longer heads is justified by the following figures :—

TABLE XXIII.

Correlation, within strains, between length of rachis and grain yield.

Strain	Co-efficient of correlation of rachis length with yield			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	0·85±0·03	0·57±0·05	0·38±0·06	0·21±0·09
Budh Perio 7	..	0·55±0·05	0·59±0·04	0·41±0·05
Moni Timberwa 7	..	0·74±0·03	0·71±0·04	0·58±0·06
Chapti 8	..	0·57±0·05	0·50±0·08	0·47±0·06
Sholapuri 1	..	0·30±0·07	..	..
Budh Perio 53	..	..	0·69±0·04	0·53±0·05
Telia Chapti 24	..	..	0·64±0·03	0·91±0·01
Telia Chapti 26	..	..	0·81±0·02	0·72±0·03
Sholapuri 18	..	..	0·58±0·07	0·42±0·05

I. The density of branches on the rachis.

The number of branches on the rachis is determined in any case by counting the number of branches from base to the tip. There is liable to be a little confusion near the tip, but in the measurement adopted, a branch having two branchlets of spikelets is nevertheless considered as one branch. The most useful figure, however, is not the total number of branches but the number per unit length (say per 10 centimeters) or, in other words, the density of branches on the earhead. The actual figures in this connection in a series of strains are as follows :—

TABLE XXIV.

Density of branches in earhead.

Strain	Average number of branches per 10 centimeters of rachis length				
	1923-24	1924-25	1925-26	1926-27	Average 1923-27
Althan Deshi 6	92·6	88·7	93·6	92·9	91·6
Budh Perio 7	..	87·8	102·1	111·2	..
Moni Timberwa 7	88·3	83·0	90·0	95·0	87·1
Chapti 8	..	70·6	75·9	80·2	..
Sholapuri 1	47·1	47·0	..	..	..
Budh Perio 53	..	..	85·2	112·9	..
Telia Chapti 24	..	..	64·8	79·8	..
Telia Chapti 26	..	..	67·4	96·0	..
Sholapuri 18	..	..	45·1	56·1	..
Local Surat *Perio*	81·4	..	82·8	98·9	..

The relative density of branches per earhead is very closely similar in the different strains in all years except 1926-27, when the condition of growth unfortunately was not very uniform in the different strains. The wider differences are quite clear, the looseness of the *Sholapuri* types, and the looseness of the *Chapti* and *Telia Chapti* strains as compared with the *Perio* types.

Within the strains, the correlation of the number of branches with yield is very close, the co-efficient of correlation being $0{\cdot}83 \pm 0{\cdot}03$ with *Althan Deshi* 6 in 1923-24, was about 0·80 in all the strains except *Sholapuri* 1 in 1924-25. It was over 0·60 in all cases in 1925-26, but was much lower in 1926-27, varying from $0{\cdot}37 + 0{\cdot}05$ with *Sholapuri* 18 to $0{\cdot}64 \pm 0{\cdot}05$ with *Moni Timberwa* 7. Within a strain, therefore, a

dense earhead, that is to say, a large number of branches in an earhead, means a high yield.

The number of seeds per branch of the rachis varies much from season to season, especially with some types. Records are only available in a few cases, but these have given the following figures :—

TABLE XXV.

Number of seeds per branch of rachis.

Strain	Average number of seeds per rachis branch			
	1923-24	1924-25	1925-26	1926-27
Allhan Deshi 6	22·6	23·8	26·5	28·4
Budh Perio 7	..	18·1	19·7	23·9
Moni Timberwa 7	19·4	22·6	21·1	25·6
Chapti 8	..	25·5	20·0	22·7
Sholapuri 1	24·8	26·5	..	..
Budh Perio 53	..	..	19·0	23·6
Telia Chapti 24	..	..	23·7	31·4
Telia Chapti 26	..	..	16·8	29·3
Sholapuri 18	..	..	21·9	28·5

It will be seen that the high number of seeds per branch is maintained in *Allhan Deshi* 6, and the number in *Budh Perio* 7 remains low throughout, others are very variable indeed.

J. The character of the seed.

(*a*) *Seed weight.* It may be noted, first, that the seed weight varies on the same earhead, the seed at the top being generally the heaviest, the middle ones coming next, and that at the base being the lightest. This is illustrated by the following figures, being the weight of 1,000 grains in 1925-26, from various parts of the earhead in a number of strains.

Top of earhead (16 per cent. of total)—48·9 grams per 1,000 grains.
Middle of earhead (57 per cent. of total)—47·7 grams per 1,000 grains.
Base of earhead (27 per cent. of total)—45·3 grams per 1,000 grains.

Average. 46·6 grams per 1,000 grains.

Taking the average weight of the seeds from the whole heads by counting 23 grams of seed, the following figures have been obtained :—

TABLE XXVI.

Weight of seeds in Surat jowars.

Strain	Weight of 1,000 seeds in grams				
	1923-24	1924-25	1925-26	1926-27	Average 1923-26
	grm.	grm.	grm.	grm.	grm.
Althan Deshi 6	37·1	43·6	30·1	52·3	36·9
Budh Perio 7	..	42·7	30·7	46·0	..
Moni Timberwa 7	37·3	45·3	33·9	49·2	38·8
Chapti 8	48·9	53·9	39·3	54·7	47·3
Sholapuri 1	33·6	39·5	..	..	..
Budh Perio 53	..	47·0	31·3	57·8	..
Telia Chapti 24	..	48·1	27·2	53·6	..
Telia Chapti 26	..	47·0	32·3	46·6	..
Sholapuri 18	..	46·6	32·1	47·4	..

Beyond the fact that the *Sholapuri* types are light seeded and the *Chapti* types are heavy headed, there seems little regularity in these figures. The actual relative size of seed seems to be far more under the influence of the environment of the particular season than to be determined by hereditary influences. Except in the broadest sense, there seems little reason for supposing that because a type gives a large seed one year, it will give a large seed in another year under different environmental conditions.

(*b*) *Seed size and uniformity.* This has been measured in two ways, namely, (1) sieving not less than five pounds of the seed through sieves having round holes 3 millimeters, 4 millimeters, and 5 millimeters in diameter. The seed sieved is then weighed and the average grade of the sample calculated from the percentage of grain under different heads. (2) by the use of the 'grain tester' which enables the weight per bushel to be determined on a small sample.

The results by each of these methods in the same lot of seeds, of four strains, in 1925-26 were as follows. The average grade of seed means the diameter of the circular holes in the sieve through which the average seed would just pass. The

grain tester reading means the volume in cubic centimeters of 150 grams of grain filled by pouring gently into the measuring vessel.

These are compared with the weight in grams of 1,000 seeds :—

Strain	Grain values in 1925-26		
	Average grade of seed	Grain Tester reading	Weight of 1,000 seeds
	mm.	c.c.	grams
Althan Deshi 6	4·07	127·2	30·1
Budh Perio 7	4·15	129·5	30·7
Budh Perio 53	4·30	127·3	31·3
Sholapuri 18	4·23	129·8	32·1

The methods do not agree with one another, and indicate that the grain tester is determining something which is not entirely dependent on grain size or grain weight but also on the capacity to pack closely.

So far as the average grade is concerned, the order of size in the seed for which we have records for three years or more is very nearly the same in each year, as the following Table shows :—

TABLE XXVI.

Average size of grains in Surat jowars.

Strain	Average grade of seed			
	1923-24	1924-25	1925-26	1926-27
	mm.	mm.	mm.	mm.
Althan Deshi 6	4·38	4·43	4·07	4·72
Budh Perio 7	..	4·45	4·15	4·53
Moni Timberwa 7	4·47	4·49	4·37	4·62
Chapti 8	4·62	4·52	4·49	4·99

The only change in order is in 1926-27 when, as already explained, there was some irregularity in planting. The size of the seed is, in fact, a hereditary quality, modified considerably by the conditions of any particular season.

The grain tester results, which represent the volume per unit weight, are also characteristic of the strain in the same sense, as the following figures show :—

TABLE XXVII.

Grain tester readings in Surat jowars.

Strain	Grain tests readings			
	1923-24	1924-25	1925-26	1926-27
Althan Deshi 6	124·4	121·5	127·2	121·3
Budh Perio 7	127·1	124·2	129·5	126·7
Moni Timberwa 7	123·1	124·1	129·0	127·3
Chapti 8	130·8	127·2	134·8	128·7

It will be noticed that the highest figures with all strains are obtained in the dry season of 1925-26, and in this year, it may be noted, that the grains were the least plump.

(c) *Seed characters.* Most of the seed characters such as colour, texture and shape appear to be fully constant, and reappear from year to year in pure line cultures. The variation of strains selected from any variety are shown below, where the characteristics of selections breeding true are given.

TABLE XXVIII.

Characteristics of seeds of Surat jowars.

Strains	Colour of seed	Texture of grain	Shape of grain
I. *Perio* types.			
Althan Deshi 6	Yellowish	Hard	Round.
Budh Perio 7	Do.	Do.	Do.
Moni Timberwa 7	Pale yellowish	Slightly less hard than above.	Flat with gloss and lustre.
Budh Perio 40	Pale yellowish with reddish tips.	Hard	Round.
Budh Perio 53	Whitish	Do.	Round and plump.
Budh Perio 26	Pale yellowish	Do.	Round.
II. *Chapti* types			
Chapti 8	White	Soft	Big and flat.
Telia Chapti 24	Pearly white	Hard	Very flat and big.
Telia Chapti 26	Do.	Do.	Flat and big.
III. *Sholapuri* types.			
Sholapuri 1	Dullwhite	Do.	Round and plump with wavy constructions on surface.
Sholapuri 18.	Pale yellowish	Do.	Round and plump.

Variability among strains of Surat jowars. The variability of the plants grown from selfed seed in any year is a measure of purity, for the variability of a pure type should remain similar from year to year. And, further, a study of the variability enables those characters to be determined, which are least variable, or, in other words, which are most characteristic of the type.

Among the characters studied, the least variable in all the strains are (1) the period from germination to flowering, (2) the length of the rachis. The purely vegetative characters (like plant height etc.) are very variable, far more so than the earhead characters like the length of the rachis or the number of branches in the earheads. Some types like *Moni Timberwa* 7 or *Chapti* 8 seem more variable than others like *Budh Perio* 7, though the variability remains similar from year to year.

The variability is best expressed by the co-efficient of variation within the strain, and the following table shows the average for three years for four strains. The cases where only two years' records are in hand are not given, but they are of a similar order to those shown :—

TABLE XXIX.

Variability of characters in strains of Surat jowars.

Characters	Co-efficient of variation			
	Althan Deshi 6	*Budh Perio* 7	*Moni Timberwa* 7	*Chapti* 8
1. Plant height	14·1±0·7	10·5±0·5	15·9±0·9	14·2±0·9
2. Leaf area per plant	24·4±1·1	21·1±1·1	26·4±1·5	22·8±1·4
3. Stem thickness	13·6±0·7	12·7±0·6	15·8±0·3	15·2±0·9
4. Number of internodes	9·7±0·4	9·5±0·4	11·5±0·6	9·8±0·7
5. Days from germination to flowering	3·2±0·2	2·5±0·1	3·0±0·2	2·8±0·2
6. Length of rachis	7·5±0·4	9·0±0·4	9·7±0·5	11·2±0·7
7. Number of branches on rachis	10·7±0·5	14·0±0·7	16·1±0·9	16·8±1·0
8. Seed weight	14·9±0·7	10·8±0·5	11·6±0·6	10·4±0·8

Yielding capacity among strains of Surat jowars. In judging the yielding capacity of a strain, and all selections made in connection with the work under record, three methods have been used.

The first of these is in single rows, three feet apart, each composed of about sixty-five plants, sown, by dibbling, direct with the produce of self-fertilized heads, the dibbles being placed at intervals of eighteen inches. The percentage

stand of plants finally obtained is noted, the actual yield is recorded, and the theoretical yield for the full number of dibbles is calculated.

The second is to obtain the yield from replications of four lines each in comparison with the local *jowar*. The yield figures are used as actually obtained, as the difference in stand of plants is negligible.

The third is to record the yield in portions of the large area devoted to seed-multiplication on the Surat Experimental Station.

Taking all these into account, the yields obtained for a series of strains for two or three years are given below. The yield figures for 1926-27 have not been taken into account in working out averages as the stand of plants that year was not even, for reasons already described.

The yield of a number of the strains in 1924-25 and 1925-26 was calculated by the first method only and these cases have been noted :—

TABLE XXX.

Yield per acre of strains of Surat jowars.

Strain	Yield per acre of grain				
	1923-24	1924-25	1925-26	1926-27	Average 1923-27
	lb.	lb.	lb.	lb.	lb.
I. *Perio* types.					
1. *Aldhan Deshi* 6	1,073	943	930	..	983
2. *Budh Perio* 7	1,075	976	909	..	987
3. *Moni Timberwa* 7	979	1,091	688	..	919
4. *Budh Perio* 53	..	1,224*	928	1,131	..
6. *Budh Perio* 26	..	1,144*	762	..	..
7. Local *Perio Jowar* Surat	719	914	556	960	730
II. *Chapti* types.					
1. *Chapti* 8	1,096	1,061	660	..	939
2. *Telia Chapti* 24	..	1,403*	741	1,151	..
3. *Telia Chapti* 26	..	1,374*	673	1,296	..
4. Local *Chapti Jowar* Surat	846	1,038	520	903	801
III. *Sholapuri* types.					
1. *Sholapuri* 1	..	1,001	840*	..	..
2. *Sholapuri* 18	..	1,302*	734	1,276	..
3. Local *Sholapuri Jowar* Surat	..	814	573	990	..

* Yield from the first method (in single rows) only.

As regards these results, it will probably be only safe to draw conclusions from those cases where proper records from three years are available. Taking the average of the three years, we have among the *Perio* types, *Althan Deshi* 6 giving 34·6 per cent. higher yield than the local *Jowar* under exactly similar conditions, with a very small variation from the mean; *Budh Perio* 7 is slightly better, on the average, than the last giving an increased yield of 35·2 per cent. more than the local *Jowar*. The variation from year to year is, however, somewhat greater than in the last case. *Moni Timberwa* 7 does exceedingly well in the very favourable season, for growth, 1924-25, but fails badly in the dry season of 1925-26. On the whole, it gives 25·9 per cent. increase on the local *Jowar*. *Budh Perio* 53 is of still greater promise, but the results are not sufficient for final conclusion.

Among the *Chapti* types it is only in *Chapti* 8 that we have material to judge the value of the selection made. Here we have, on three years' average, an increased yield of 17·2 per cent. The *Telia Chapti* selections promise to be still better. No final conclusion can be specified regarding the *Sholapuri* types, but one at least promises well, and will probably give over 20 per cent. increase of yield.

In general, it seems as if, by simple selections, an increase in yield of grain of twenty per cent. or thereabouts can usually be obtained in a crop as highly mixed as the Surat varieties of *Jowar*—besides the extra value which is given for the more even grain obtained from a single pure strain of the crop.

Description of certain pure bred strains of Surat Jowar

The characters which differentiate the *Kharif Jowars* of the Surat District from one another have been already described. But the discussion which has followed has shown that all the recognised varieties of the crop are mixtures of strains, which differ from one another by characters of direct or indirect economic importance, and which breed true. These strains are, however, not merely mixed. They have crossed with one another to a very great extent, and few, if any, of a pure character now exist in cultivation. Any attempt to make a permanent improvement in yielding capacity, or even to fix a type which shall approach near to the ideal for this District, must be commenced by the isolation of such pure strains breeding true, which can be used as the basis for establishing types or of making crosses with other varieties.

It is now proposed to describe ten such pure strains, five belonging to the *Perio*, three to the *Chapti* and two to the *Sholapuri* variety, in order to indicate the range of variation in the variety and also the fluctuation within the strain itself. They are only a few examples from a large number of strains isolated, and they are simply described as examples, for the purposes above indicated. The figures of growth etc. are comparable between the strains and are obtained at Surat.

The five strains *Althan Deshi* 6, *Budh Perio* 7, *Moni Timberwa* 7, *Chapti* 8 and *Sholapuri* 1 were isolated in 1922-23 from types growing on the Government

Farm, Surat, and have been grown from self-pollinated seeds ever since. Selection 40 was selected in 1922-23, and has been grown from self-pollinated heads since 1923-24. The remaining strains have been isolated from a number of samples collected in 1922-23 in the Bardoli and Chorashi talukas of the Surat district, and the adjoining areas of the Baroda State, and grown ever since from self-pollinated seeds.

(1) Budh Perio 7.

Habit of growth and vegetative characters. This type is tall, grows vigorously and continuously. The internodes are long. The leaves are longer and narrower than those of *Althan Deshi* 6 and *Moni Timberwa* 7. They are hairy at the tips and the midrib is greenish. The stem is thicker than that of *Althan Deshi* 6. The leaf area is relatively high.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	145	13	38·8	3,609
1924-25	171	16	38·9	4,166
1925-26	178	18	44·9	5,929
1926-27	104	11	50·3	4,099

Flowering habit and character of inflorescence. The average number of days from germination to flowering was :—1923-24—115 days ; 1924-25—105 days ; 1925-26—107 days ; 1926-27—141 days. The last is not comparable with the others. The shrivelled anthers are brown, the stigma appeared 20 hours before the bursting of the anthers in 1926-27. The peduncle is long and curved.

Earhead character. The heads are compact, bulging in the middle, and are blunt, with a characteristic narrow depression below the tip due to shorter lenth of two or three whorls below the last, and the relatively long branches at the tip. The length of rachis is long for such a compact type, and has been as follows :—1924-25—9·2 cm., 1925-26—10·2 cm., 1926-27—9·5 cm. The number of rachis branches is high, being second only (per unit length of earhead) to *Budh Perio* 53. The number per 10 cm. length of rachis has been as follows :—1924-25—88 ; 1925-26—102 ; 1926-27—111. The number of seeds per branch is small, less than any other *Perio* type, as follows :—1924-25—18·9 ; 1925-26—19·7 ; 1926-27—23·9.

Seed character. The grains are yellowish, hard, and round but are light in weight, 1,000 grains weighed 42·7 grams in 1924-25 ; 30·7 grams in 1925-26 ; and 46 grams in 1926-27. As is usual with compact types, the seeds are not very uniform. The

average grade has been in 1924-25—4·45 mm.; in 1925-26—4·15 mm.; and in 1926-27—4·53 mm.

(2) Althan Deshi 6.

Habit of growth and vegetative characters. This type is rather medium in height, particularly the top five internodes which are very short. The stem is also relatively thin. The leaves are shorter and broader than those of *Budh Perio* 7 and have rather less leaf area per plant. They are hairy at the tips and the midrib is greenish. The waxy coating on the sheaths is well developed. The colour of leaves is dark green.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	115	13	32·5	3,046
1924-25	163	16	38·1	4,099
1925-26	158	18	42·4	5,127
1926-27	103	13	50·9	4,373

Flowering habit and character of inflorescence. The average number of days from germination to flowering was:—1923-24—114 days; 1924-25—100 days; 1925-26—101 days; 1926-27—125 days. The shrivelled anthers are yellow. The number of pedicelled flowers with anthers is the highest.

Earhead characters. The heads are very compact, of moderate size and less blunt than in *Budh Perio* 7. The peduncle is curved and short. The length of rachis is the shortest in *Perio* strains, being only slightly longer than that of *Chapti* 8. It has been as follows:—1923-24—7·9 cm.; 1924-25—8·1 cm.; 1925-26—8·3 cm.; 1926-27—9·1 cm. The number of rachis branches is moderate, the number per 10 cm. length of rachis has been as follows:—1923-24—93; 1924-25—89; 1925-26—94; 1926-27—93. The number of seeds per branch is highest, particularly in relation with the short length of the branches. It has been as follows:—1923-24—22·6; 1924-25—23·8; 1925-26—26·5; 1926-27—28·4.

Seed characters. The grains are yellowish, hard, plump and round. The seed weight is similar to that of *Budh Perio* 7 and 1,000 grains weighed 37·1 grams in 1923-24; 43·6 grams in 1924-25; 30·1 grams in 1925-26; and 52·3 grams in 1926-27. As is usual with the compact types, the seeds are not very uniform. The average grade has been in 1923-24—4·38 mm.; in 1924-25—4·43 mm.; in 1925-26—4·07 mm.; and in 1926-27—4·72 mm.

(3) Budh Perio 40.

This was selected from farm *jowar* for earliness and most of the characters reveal it to be rather nearer to the type of *Nialo jowar* than to the *Perio* variety. It has been studied only for the first two years.

Habit of growth and vegetative characters. This type is short and thin and produces few nodes. The leaves are long and very narrow and have the smallest leaf area of all the Surat *jowars* isolated. The leaves are almost glabrous and have greenish midrib.

Year	Average total height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	109	13	30·5	2,386
1924-25	163	16	32·5	2,931

Flowering habit and character of inflorescence. The average number of days from germination to flowering is the lowest and has been in 1923-24—112 days and 1924-25—93 days. The shrivelled anthers are red. The number of pedicelled flowers with anthers was very small.

Earhead characters. The heads are semi-compact, of moderate size and almost cylindrical in shape with long straight peduncle. This has not been studied in details as it is a low yielder.

Seed characters. The grains are whitish yellowish with reddish tips, hard, and round but small.

(4) Moni Timberwa 7.

This type was originally selected from a local sample of the famous locality *Moni Timberwa* renowned for the best quality of grain.

Habit of growth and vegetative characters. This type is intermediate in height between *Budh Perio* 7 and *Althan Deshi* 6 with thick stems. The leaves are longer and broader and thus have the largest leaf area per plant. The leaves are hairy at the tips, the number of hairs being large and the midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	126	13	36·2	3,641
1924-25	165	16	41·1	4,798
1925-26	156	18	44·3	5,823
1926-27	81	10	46·0	3,284

This type gives less tillers after harvesting and suffers badly in dry years.

Flowering habit and character of inflorescence. This is rather a late flowering type. The average number of days from germination to flowering was :—1923-24—118 days; 1924-25—105 days; 1925-26—111 days; and 1926-27—144 days. The last is not comparable. The shrivelled anthers are yellow.

Earhead characters. The heads are less compact than of *Budh Perio* 7, are of moderate size, with basal spikes projecting. The length of rachis is shorter than that of *Budh Perio* 7 and has been as follows :—1923-24—8·8 cm.; 1924-25—8·9 cm.; 1925-26—9·2 cm.; 1926-27—8·9 cm. The number of rachis branches is less than *Budh Perio* 7 but greater than *Althan Deshi* 6, while average number per 10 cm. length is less than in *Althan Deshi* 6, indicating less compactness of the heads. It has been as follows :—1923-24—88; 1924-25—83; 1925-26—90; 1926-27—95. The number of seeds per branch is low, being only greater than in *Budh Perio* 7, as follows :—1923-24—19·4; 1924-25—22·6; 1925-26—21·1; 1926-27—25·6.

Seed characters. The grains are pale yellowish, flat, and big with good lustre and are uniform. It is less hard than in previous strains. These grain characters, *viz.* size and lustre, are maintained in dry year, but when sown late deteriorate; 1,000 grains weighed 37·3 grams in 1923-24; 45·3 grams in 1924-25; 33·9 grams in 1925-26; and 49·2 grams in 1926-27. The average grade has been in 1923-24—4·47 mm.; in 1924-25—4·49 mm.; in 1925-26—4·37 mm.; and in 1926-27—4·62 mm.

(5) Budh Perio 53.

This was selected in 1923-24 and was grown from selfed heads since then.

Habit of growth and vegetative characters. This type is shorter than *Budh Perio* 7 but has the thickest stems. The leaves are large and the leaf area per plant is in some years the highest among all our strains. The leaves are sparsely hairy and are drooping. The midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1925-26	154	19	44·0	5,563
1926-27	130	14	60·1	6,002

Flowering habit and character of inflorescence. It has the late flowering habit, though it ripens at the same time as other strains. The average number of days from germination to flowering was 119 days in 1925-26 and in 1926-27 was 138. The shrivelled anthers are red. The stigma is also pinkish. The inflorescence when out from flag gives a flattened appearance on both sides.

Earhead characters. The heads are long, semi-compact and are the biggest among the compact and semi-compact types. The basal spikes are projecting. The length of rachis has been as follows :—1925-26—11·2 cm. and in 1926-27—11·5 cm. The number of rachis branches is very high. It is also very high per unit length of earhead, the number per 10 cm. length of rachis has been 85 in 1925-26 and in 1926-27, 113. The number of seeds per branch is small. It was 19 in 1925-26 and in 1926-27 it was 23·6.

Seed characters. The grains are whitish round plump and hard. The seed weight in ordinary seasons is heavier than that of the strain last described. 1,000 grains weighed 47 grams in 1924-25 ; 31·3 grams in 1925-26 ; and 57·8 grams in 1926-27. The average grade has been in 1925-26—4·30 mm. and in 1926-27—4·58 mm.

(6) Chapti 8.

The description of this type is the representative of the *Chapti variety.*

Habit of growth and vegetative characters. This type is of the same height as *Moni Timberwa* 7. However, the stem is the thinnest, being only thicker than *Selection* 40. The leaves are sparsely hairy. The tips of leaves are very sparsely hairy, and the hairs are seen towards the midrib. The midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Leaf area per plant
	cm.		mm.	sq. cm.
1923-24	143	14	38·2	3,905
1924-25	163	16	38·3	4,147
1925-26	134	17	37·4	4,270
1926-27	91	11	43·0	3,346

Flowering habit and character of inflorescence. The period for flowering is the same as that of *Budh Perio* 7 or little late. The average number of days from germination to flowering was :—1923-24—116 days ; 1924-25—105 days ; 1925-26—111 days ; and 1926-27—145 days. The shrivelled anthers are whitish yellow. The number of pedicelled flowers with anthers is very low, even less than in *Budh Perio* 40. There are no hermaphrodite flowers with two staminate flowers attached. The peduncle is curved.

Earhead characters. The heads are of moderate size and are semi-compact as though they are compact at the base, they are slightly loose at the top and broad and bulging at the base. The length of the rachis is the shortest among all strains and has been as follows :—1924-25 and 1925-26—7·7 cm. and 1926-27—8·4 cm. The number of rachis branches is also the least among all strains. However, as the rachis length is short, the numbe. of branches per unit length seem

moderate. It has been per 10 cm. of rachis length :—1924-25—71 ; 1925-26—75 ; 1926-27—80 cm. The number of seeds per branch is low and has been as follows : —1924-25—25·5 ; 1925-26—20 ; and 1926-27—22·7.

Seed characters. The grains are milky white, flat and big and soft. It has the heaviest grains nd the weight is comparatively maintained whatever may be the nature of the seasons. 1,000 grains weighed 53·9 grams in 1924-25 ; 39·3 grams in 1925-26 ; and 54·7 grams in 1926-27. The average grade has been in 1923-24—4·62 mm. ; in 1924-25—4·52 mm. ; in 1925-26—4·49 mm.; and in 1926-27 —4·99 mm.

(7) Telia Chapti 24.

This type is a selection from the variety " *Telia Chapti* " which has flat seeds, yet they are hard and pearly yellow, and fetches the highest price.

Habit of growth and vegetative characters. This type is dwarf in habit, being even shorter than *Althan Deshi* 6. The stems are thick ; it looks very leafy as the leaves are broad. The leaves are nearly glabrous and have greenish midrib.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1925-26	122	18	41·4	4,863
1926-27	115	13	54·8	5,416

Flowering habit and character of inflorescence. It is late in flowering. The average number of days from germination to flowering was 120 days in 1925-26 and 145 days in 1926-27. The shrivelled anthers are red. The peduncle is curved.

Earhead characters. The heads are of moderate size. They are compact at the base but rather loose at the top. The length of rachis is long and has been 10·3 cm. in 1925-26 and 1926-27—10·6 cm. The number of rachis branches is moderate but it is much decreased in a dry season. The number per 10 cm. length of rachis is the lowest among all compact and semi-compact types and has been 65 in 1925-26 and 80 in 1926-27. The number of seeds per branch is the highest and has been 23·7 in 1925-26 and in 1926-27, 31·4.

Seed characters. The grains are pearly yellow, very flat, big and hard. They are heavy in weight, but it is much affected in a dry season ; 1,000 grams weighed 48·1 grams in 1924-25 ; 27·2 grams in 1925-26 ; and 53·6 grams in 1926-27. The average grade has been 3·99 mm. in 1925-26 and in 1926-27—4·92 mm.

(8) Telia Chapti 26.

This was selected from the local variety in the same way as the strain last described.

Habit of growth and vegetative characters. This type is moderate in height and the stems are thinner than those of *Telia Chapti* 24. The tallness is due to long internodes. The leaves are rather small and the leaf area per plant is rather low. They are glabrous and the midrib is greenish.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1925-26	138	18	39·1	4,172
1926-27	122	13	52	4,677

Flowering habit and character of inflorescence. It is late in flowering like *Telia Chapti* 24. The average number of days from germination to flowering was 120 days in 1925-26 and in 1926-27, 145 days. The shrivelled anthers are red.

Earhead characters. The heads are semi-compact, bulging a little above base. Peduncle is inclined. The length of rachis is very long and has been 11·2 cm. in 1925-26 and 10·5 cm. in 1926-27. The number of rachis branches is rather high. The number per 10 cm. length of rachis has been 67 in 1925-26 and in 1926-27—96. The number of seeds per branch has been 16·8 in 1925-26 and in 1926-27, 29·3.

Seed characters. The grains are flat, hard, pearly yellow and are more plump than in *Telia Chapti* 24. The seeds are lighter in weight than in *Telia Chapti* 24. 1,000 seeds weighed 47 grams in 1924-25; 32·3 grams in 1925-26; and 46·6 grams in 1926-27. The average grade has been 4·15 mm. in 1925-26 and 4·59 mm. in 1926-27.

(9) Sholapuri 1.

This type is the typical representative of the lax group of Surat *jowars.*

Habit of growth and vegetative characters. This type is taller than the general variety due to the longer internodes, particularly the top five, though the latter are shorter than those of *Sholapuri* 18. The stem is rather thin. The leaves are long but narrow. They are practically glabrous at the tip, the midrib is white, which is almost universal in the variety, and thus the stem is pithy.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1923-24	127	13	35·0	3,422
1924-25	179	16	30·4	4,694

Flowering habit and character of inflorescence. It is as late as *Moni Timberwa* 7. The average number of days from germination to flowering was :—1923-24 —121 days; 1924-25—105 days; 1925-26—107 days. The shrivelled anthers are typically red. Pedicelled flowers with anthers were altogether absent in 1926-27—quite a novel feature. The peduncle is long and straight generally.

Earhead characters. The heads are loose, big and cylindrical. The length of rachis is exceptionally long, common to the lax group. It was 14·2 cm. in 1923-24 and 13·6 cm. in 1924-25. The number of rachis branches is low. The number per 10 cm. length of rachis is very low and has been 47 in 1923-24 and in 1924-25. The number of seeds per branch is high and has been 24·8 in 1923-24 and 26·5 in 1924-25.

Seed characters. The grains are dull whitish, small, round, plump and hard with wavy constrictions on the seed surface. 1,000 grains weighed 33·6 grm. in 1923-24 and 39·5 grm. in 1924-25. They are the lightest among all strains. The average grade has been 4·28 mm. in 1923-24 and 4·44 mm. in 1924-25.

(10) Sholapuri 18.

Habit of growth and vegetative characters. This type is medium in height, though the top five internodes are very long. It has a low leaf area per plant. The leaves are sparsely hairy and have a white midrib. The stems are pithy.

Year	Average height	Average no. of nodes in stem	Average stem thickness	Average leaf area per plant
	cm.		mm.	sq. cm.
1925-26	155	18	43·2	4,764
1926-27	124	12	49·7	4,372

Flowering habit and character of inflorescence. It is late in flowering. The average number of days from germination to flowering was 116 days in 1925-26 and 146 days in 1926-27. The shrivelled anthers are yellow, rather uncommon for the variety. The peduncle is rather short.

Earhead characters. The heads are loose, very long, tapering and big. The length of rachis is the longest among all strains and was 15·7 cm. in 1925-26 and 15·1 cm. in 1926-27. The number of rachis branches is very low, being only greater than in *Chapti* 8; while the number per 10 cm. length of rachis is the lowest and has been 45 in 1925-26 and 56 in 1926-27. The number of seeds per branch is as follows :—1925-26– 21·9 and in 1926-27—28·5.

Seed characters. The grains are pale yellow, hard, plump and round; 1,000 seeds weighed 46·6 grams in 1924-25; 32·1 grm. in 1925-26; and 47·4 grams in

1926-27. The average grade has been in 1925-26—4·23 mm. and in 1926-27—4·48 mm.

The ideal Jowar plant for Surat.

The study, of which an account has been given, has led to a very clear conception of the type of *jowar* plant which should be arrived at under the condition of the Surat District. Naturally, the prime necessity is a high yield of grain, but there are certain associated characters which make a plant specially suitable under the conditions.

Habit of growth. A tall plant having long internodes is desirable, with a large number of nodes and hence a large leaf surface. Shorter internodes in the upper part of the stem seems associated with compact heads. Such plants, too, do not lodge, whereas plants which have longer internodes in the upper part of the stem tend to have loose heads, and also tend to lodge,—as is the case with all *Sholapuri* strains, and this is a distinct objection against this variety.

Leaf area per plant. While a large leaf area is closely correlated with high yield, yet, on the whole, it appears that types with medium leaf surface like *Althan Deshi* 6 are to be preferred, taking all seasons together. *Moni Timberwa* 7, which has the largest leaf surface among the selections described, does not fare well particularly in dry seasons.

Wax on the stems. The presence of wax on the stem is considered by many workers to be a sign of drought resisting character, and certainly the selection *Althan Deshi* 6, in which it is largely developed, does the best in a dry season. The relation of wax to drought resistance is not yet, however, clear. As to the advantage or disadvantage of hairiness on leaf, little can be said though there is a general belief that the glabrous types (like *Chapti*) do best in moisture retentive soils, and the hairy ones like *Perio* and *Sholapuri* where there may be water deficiency.

Habit of leaves. In dry years, all *Jowar* types make their leaves nearly erect in the middle of the day, and in some strains this is very highly developed. It is a desirable character to encourage on soils where moisture is likely to be short. The *Vani* variety has this character to a marked extent.

Colour of leaves. After two or three months' growth, a dark green colour is always considered as a sign of healthy robust growth. It should always be preferred to a lighter colour of the leaves.

Flowering habit. The *Jowars* of the Surat District are generally late in flowering, and a type flowering and ripening earlier, when planted at the usual time, would be of considerable advantage. *Sholapuri* types are capable of being planted late, but if planted at the usual time, they do not flower earlier than some of the *Perio* selections. The general late flowering habit in Surat appears to be due to the fact that if the peduncle emerges during August and September, it is very likely to be attacked by insect pests, especially by the borers (*Chilo simplex* and *Sesamia inferens*). How to meet the demand for an early

flowering type, and yet one which will avoid these pests, is not yet quite clear. Very markedly late flowering types, even though they ripen at the same time as others, are not desirable.

Types having recessive characters in the inflorescence—such as yellow anthers—are desirable, so as to make it easy to keep the types pure.

Earhead. Cultivators prefer compact headed types of *jowar*, as they are generally believed to be heavy yielders. This belief does not appear to be entirely well founded as *Budh Perio* 53 and *Telia Chapti* 26, which are semi-compact types, and *Sholapuri* 18, which is a loose type, are high yielders. Compact headed types usually give a grain very much more mixed in size. A semi-compact head is, on the whole, to be preferred.

The loose headed types are supposed, also, to be less attacked by birds, but, on the other hand, all these have a tendency to lodge.

They also have a larger amount of cross-fertilization and this is not a desirable character.

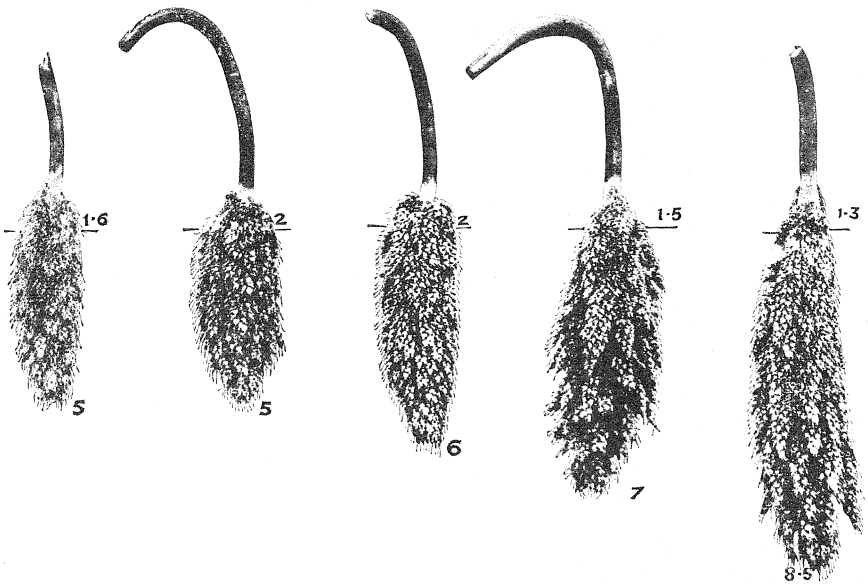
In semi-compact headed types, the head should be big, as otherwise low yields may result.

Grain. The seeds should be large and dense. Bigger grain is always preferred by consumers, and such large grains are usually also flat. Flat and hard types, in our experience, have not maintained their character well in years of drought. Soft grains have the disadvantage of being more easily attacked by weevils.

As to colour, very white grains are usually preferred by Parsis and not by others. Generally, the types with pearly yellow colour with good lustre are preferred. Such a kind is the *Moni Timberwa* 7 strain, but it does not maintain this character when sown late.

Straw. (*Kadbi*). Jowar straw should not be hollow. As the character of the straw in this respect can be noticed from the colour of the midrib of the leaf such types can be eliminated A green leaf midrib means desirable straw. Other things being equal, the *Kadbi* should be thin, though heavy grain yielders are almost invariably thick stemmed types. Comparatively thin straw can be found in combination with moderately good yield in *Althan Deshi* 6 and it should not be impossible to combine the two desirable characters.

Acknowledgments. We are under very considerable obligations to Dr. H. H. Mann, Director of Agriculture, Bombay Presidency, Poona, who guided the work and gave very valuable suggestions during the course of study.



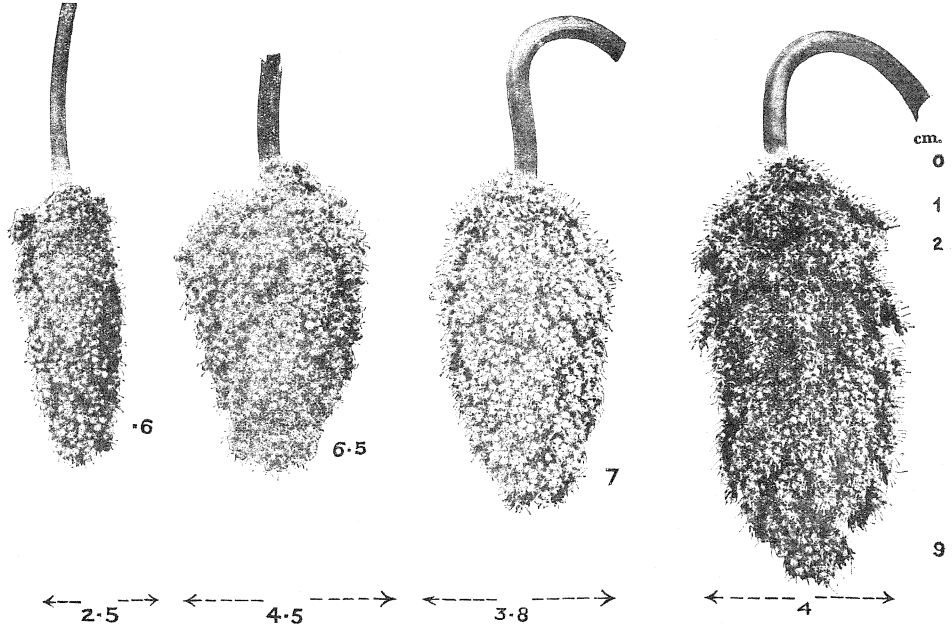
Showing differences in shape and size of inflorescence as revealed by the length of rachis and greatest breadth of inflorescence in cm.

From right 1 and 2. *Sholapuri* 1 and 21 (respectively): At the base they are narrow with very few branches. Rachis long and branches sparse and long. There is a regular gradation as to the breadth showing the looseness.

3. *Budh Perio* 53: Rachis intermediate in length. Also intermediate in looseness (*i.e.* in greatest breadth).

4 and 5. *Moni Timberwa* 7 and *Altham Deshi* 6: Rachis less in length, but in the former more bulging at the base and not as compact as in the latter.

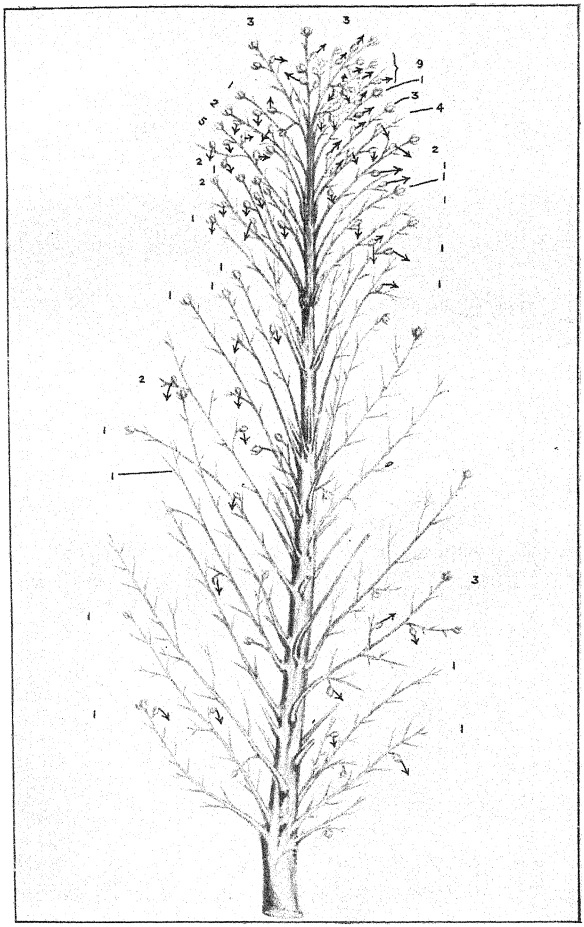
PLATE I.



Showing difference in mature heads of *Perio* types (from right):—

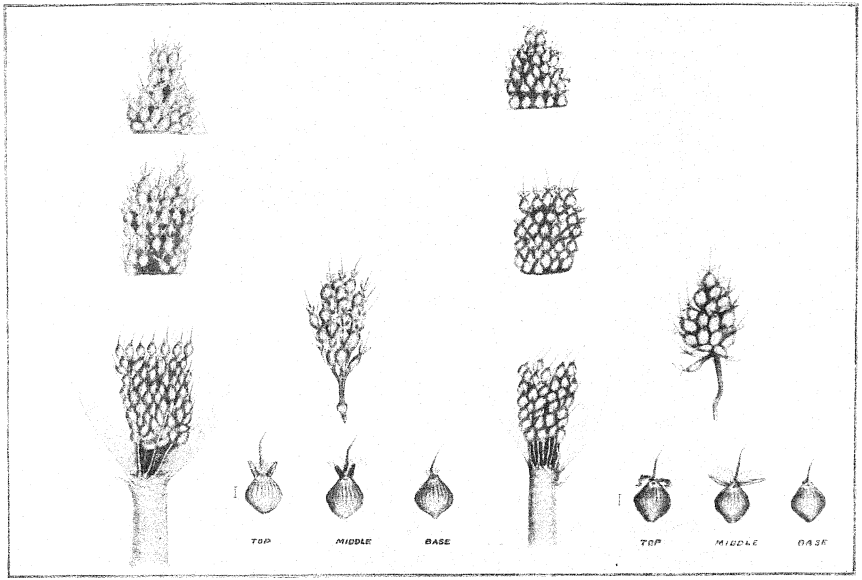
1. *Budh Perio* 53: Big, semi-compact, *i.e.* long rachis and greater breadth, *i.e.* 4 cm.
2. *Moni Timberwa* 7: Big head, more compact than *Budh Perio* 53 with no bend at the top as seen in *Budh Perio* 7.
3. *Bodh Perio* 7: Compact and blunt head with a characteristic narrow bend just below the tip (in fact bulging) as represented by the greatest breadth 4·5.
4. Selection 40: Semi-compact, uniformally broad all along, representing a cylinder.

PLATE II.



Showing how the male flowers or empty spikelets are distributed in *Budh. Perio,* No. "40."

Only a few spikelets are shown out of a large number. The arrow heads show the pedicelled male spikelets. The lines round hermaphrodite spikelets represent empty pedicelled spikelets. Figures show the number of pedicelled staminate flowers on each branch. Most of the staminate flowers are in the upper portion and are also at tips of branchlets.

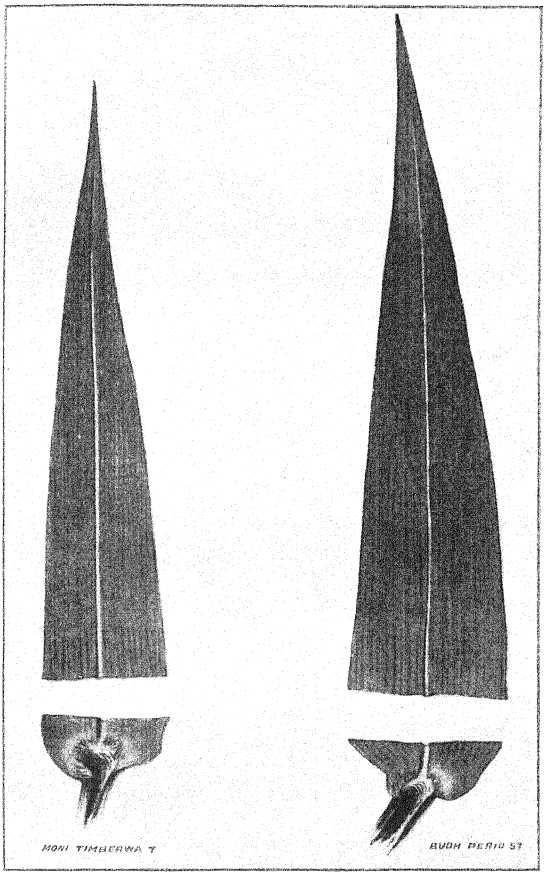


Showing difference in the emergence of styles and anthers when most flowers open on a single day.

Left to right :—

No. I. Striga resistant type :—*Top.*—Anthers shrivelled up seen (styles not seen, *i.e.*, shrivelled up). *Middle.*—Styles and anthers almost on level and bent much (styles) and anthers coming out prominently. *Base.*—Stigma just coming out and no anthers. No. II. *Althan Deshi* 6 :—*Top.*—Dried up feathery stigmas with yellow anthers out. *Middle.*—Feathery long styles bent slightly with anthers protruding at the base of the stigma. *Base.*—Flowers without any feathery ends.

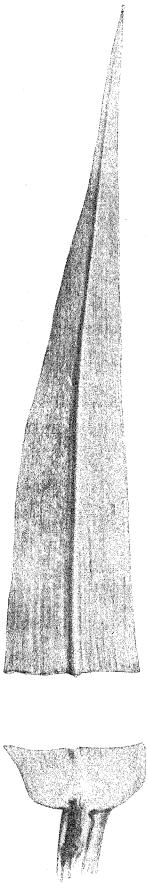
PLATE IV.



The hairs are magnified in the drawings to make them more visible :—

(3) Moni Timberwa 7 : " Very hairy Type." The hairs are profusely prominent, long and persistent. On an average the hairs are found on the length of 23 cm. out of the total length of 51 cm. They are fading to some extent from the midrib as we see downwards.

(4) Budh Perio 57 : Hairy Type. On an average the hairs are seen on the length of 21 cm., out of total length of 69 cm. though extremely minute hairs are found almost all over, *i.e.*, not quite glabrous surface. They are sparse round midrib as we see downwards towards the midrib.



CHAPTI 8

BUDH PERIO 9

The hairs are magnified in the drawings to make them more visible. 1. *Chapti* 8. "Sparsely hairy type." On an average, the hairs are seen on the length of 16 cm. out of total length of 58 cm. Hairs are very minute as compared with other strains but dense on the surface of 16 cm. at the top. They are fading from the midrib or away from the midrib downwards towards the middle. 2. *Budh Perio* 9. On an average the hairs are seen only on the length of 13 cm. out of the total length of 56 cm. Extremely minute hairs are seen almost all over the leaf. The hairs are found away from the midrib towards the middle of the leaf for a very short distance.

CONTENTS

DESCRIPTION OF THE PLATES

STUDIES IN INDIAN CHILLIES.

(1) THE TYPES OF CAPSICUM.

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I. Introduction.

Chillies constitute one of the most valuable of the minor crops of India. No separate statistics of production and acreage are available, the figures for this crop being included in the official returns under the heading of "Condiments and spices." In Madras, the province with by far the largest production of chillies, the area under "condiments and spices" is estimated at about 700,000 acres of which probably about 300,000 acres are under chillies. The crop is also cultivated fairly extensively in Northern India where in Bihar it forms a profitable alternative to tobacco. In Gangetic India generally it is a cold weather crop, transplanting taking place about September and harvesting about January-February. In the North-West, however, the season is different and in the Peshawar valley chillies are transplanted in April and harvested about the end of October.

The bulk of the chillies grown in India are consumed locally and the export trade is small but steady, being in the neighbourhood of 16 million pounds a year. About 44 per cent. of the total exports go from Bengal and 38 per cent. from the Madras Presidency. The largest customers are Ceylon and the Straits Settlements, which countries absorb over 80 per cent. of the total exports.

The present investigation was started in 1924 with the object of isolating the different types of chillies growing in India as a preliminary to the study of the inheritance of characters in the crop and with the possibility of obtaining types of chilli which would prove more valuable in yield and quality than those commonly cultivated at present. Some 52 types are described and classified, of which three are foreign varieties and the remainder are Indian. The biology of the flower has been studied and the authors desire to acknowledge the assistance received from Mr. R. B. Deshpande, post-graduate student in the Section, in this portion of the work.

II. Biology of the flower.

The genus Capsicum belongs to the Solanaceae. The flowers [1], [2] are pedicelled. axillary, solitary or 2-3 together. Calyx campanulate, sub-entire or minutely 5-toothed much shorter than fruit. Corolla rotate; lobes five, valvate in bud. Stamens 5, attached near the base of the corolla; anthers not longer than the filaments, dehiscing longitudinally. Ovary 2, rarely 3-celled; style linear, stigma subcapitate.

1. Bending of the pedicel.

In the young stage when the bud is small the pedicel is straight. As the flower bud becomes older the pedicel elongates and becomes bent so that the bud before opening takes up a more or less inverted position. In the varieties of chillies which possess pendent fruits, the bend in the pedicel occurs near the base and the flower is completely inverted and pendent (Text Fig. 1, Type 25), but in the case of types with erect fruits the bend takes place near the top of the pedicel (Text Fig. 1, Type 21) and the flower may be either pendent or in a more or less horizontal position. When the bend is near the base of the pedicel, it is permanent and the fruit is therefore pendent (Text Fig. 1, Type 25); but when the bend is near the top of the pedicel, it tends to straighten out after fertilization and as a result the fruit becomes almost erect (Text Fig. 1, Types 21, 22). In this latter case the time taken in assuming the erect position is from 8 to 19 days after flowering.

2. Flowering.

In nearly all crops the time at which the flowers open varies with the diurnal temperature. On warm days and when there is little or no dew, the flowers open earlier than on cold and dewy mornings. Flowering begins in Bihar about September and is practically continuous throughout the cold weather up to February. Observations on the opening of flower buds were taken between the 19th November and 27th November 1927 and on the 13th January 1928; the climatic conditions during this period were as follows:—

Date	Temperature			Humidity	Rain
	8 A.M.	Maximum	Minimum	8 A.M.	
				Per cent.	
19th November 1927	60·7	79·3	56·7	92	*Nil.*
20th November 1927	61·1	79·9	56·9	96	*Nil.*
21st November 1927	60·1	79·2	55·5	95	*Nil.*
22nd November 1927	59·7	78·0	54·5	90	*Nil.*
23rd November 1927	59·8	77·4	55·2	95	*Nil.*
24th November 1927	58·3	78·5	53·9	91	*Nil.*
25th November 1927	58·9	77·7	54·5	93	*Nil.*
26th November 1927	63·0	79·4	57·6	92	*Nil.*
27th November 1927	61·8	81·1	58·0	91	*Nil.*
13th January 1928	49·8	73·8	43·9	95	*Nil.*

[1] Hooker, Sir J. D. Flora of British India, Vol. IV, page 238.
[2] Prain, Sir D. Bengal Plants, Vol. II, page 747.

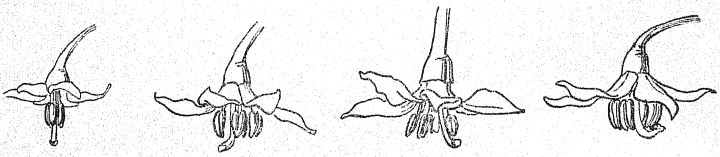
TEXT FIG. 1. A branch from Type 21 showing an erect mature fruit and stages in the assumption of the erect position from the bud to the fruit.
A branch from Type 22 showing how erect fruits may fall to a horizontal position.
A branch from Type 25 showing a pendent fruit and stages in the development of the fruit.

In November the buds begin to open at about 7-30 A.M. and continue opening up to 1 P.M.; the majority of the buds, however, which open on any one day do so between 8 A.M. and 10 A.M. Those buds which open late in the day remain in a half opened state until the following day when they become fully open somewhat earlier than other flower buds which are opening for the first time on that day. Among 114 flower buds, which were observed on the above-mentioned dates in November, 7 became fully open between 7-30 and 8-30 A.M., 52 between 8-30 and 9-30 A.M.,

33 between 9-30 and 10-30 A.M., 14 between 10-30 and 11-30 A.M., 6 between 11-30 and 12-30 and 2 between 12-30 and 1-30 P.M. On the 13th January, however, out of 20 buds 3 opened between 12 noon and 1 P.M., 2 between 1 and 2 P.M., 6 between 2 and 3 P.M., and 9 buds became incompletely open but opened fully on the morning of the next day.

3. Pollination.

The style is generally straight and usually longer than the stamens, though on the same plant flowers with the style shorter than the stamens and flowers with the style about the same length as the stamens can be found. The length of the style and the fact that the flower is inverted renders it unlikely that self-fertilisation will take place unless the plant is agitated by wind. At the commencement of this research, when chilli plants were first bagged to procure selfed seed, it was found that seed setting under bags was very scanty. This was due to the fact that plants under bags were kept in an unnaturally close and fixed position; shaking the bags once a day at 2 P.M. resulted in abundant seed setting. In many varieties of chilli, a certain percentage of the flowers possess curved styles instead of straight styles; this shortens the distance between stigma and anther and at the same time places the stigma in a more favourable position for receiving the pollen. The examination of nearly 300 flowers in three different types showed that about one-third of the flowers had styles which showed varying degrees of curvature (see Text Fig. 2.). Self-fertilisation is; therefore, more probable in such flowers.



TEXT FIG. 2. Stages in the curvature of the style.

The anthers burst some time after the flower is open. Out of 37 flowers which were observed in November 1927, in 10 flowers the anthers burst half an hour after the flower had opened, in 8 flowers after an hour, in 5 flowers after 1½ hours, in 3 flowers after 2 hours, in 3 flowers after 2½ hours, in 4 flowers after 3 hours, in 2 flowers after 4 hours and in 2 flowers after 5 hours. The delay in the bursting of the anthers favours cross-fertilisation and in factin some flowers stigmas have been found covered with pollen before the dehiscence of the anthers has taken place. Bees and ants visit the flowers in moderate numbers.

The flowers remain open for two or three days and in Bihar do not close at night. The closing which is described by Shrivastava [1] as taking place in the Central Provinces was not observed at Pusa. The corolla generally drops within two or three days after the flower is fully open, but it may persist for a longer time. Out of 93 flowers which were observed in November 1927, the corolla fell in 2 flowers on the first day after the flower was fully open, in 26 flowers it fell on the second day, in 48 flowers on the third day, in 11 flowers on the fourth day, in 4 flowers on the fifth day and in 2 flowers on the sixth day. The fruit ripens in 2 to 2½ months from the opening of the flower.

4. Cross-fertilisation.

It is evident from the above that in chillies both cross and self-fertilisation takes place and indeed that in nature there is probably, under suitable conditions, a considerable amount of crossing. Thus in 23 cultures, each culture being the progeny of a single plant which had been bagged, 21 cultures bred true to the parent type and 2 cultures showed splitting, while in 96 cultures of which the parents were not bagged only 21 bred true to the parent type and 75 showed splitting. As the different parent plants were grown in lines next to one another, the conditions were very favourable for making obvious the results of any natural crossing in the case of unbagged plants. The splitting in the case of the two cultures from bagged plants is, of course, to be attributed to the heterozygous condition of the parents.

The segregation of characters in these cultures suggests that in the fruit yellow colour and the erect habit are recessive to red colour and the pendent habit. The details of the cultures in which segregation into red and yellow and erect and pendent fruits took place were as follows :—

Parent Fruit red	Progeny		Total number of plants in culture
	No. of plants with yellow fruits	No. of plants with red fruits	
Culture No. 3 of 1927	7	11	18
,, ,, 4 of 1927	9	18	27
,, ,, 8 of 1927	14	13	27
,, ,, 6 of 1927	2	25	27
,, ,, 9 of 1927	10	8	18
,, ,, 10 of 1927	3	23	26
,, ,, 13 of 1927	3	15	18
,, ,, 14 of 1927	2	23	25
,, ,, 19 of 1927	14	13	27
,, ,, 41 of 1927	4	4	8
,, ,, 2 of 1928	3	14	17
Total	71	167	238

[1] Shrivastava K. P. Account of the Genus Capsicum grown in Central Provinces and Berar. *Bull*, 5, *Dept. Agri., Central Provinces*, 1916.

Parent Fruit pendent	Progeny		Total number of plants in culture
	No. of plants with erect fruits	No. of plants with pendent fruits	
Culture No. 7 of 1927	2	16	18
„ „ 39 of 1927	10	14	24
„ „ 5 of 1928	1	25	26
„ „ 18 of 1928	12	15	27
„ „ 22 of 1928	5	22	27
„ „ 23 of 1928	6	21	27
„ „ 26-1 of 1928	18	9	27
„ „ 28-1 of 1928	6	22	28
Total	60	144	204

III. Systematic.

(*I*) *General.*

Notwithstanding the wide-spread cultivation of the genus *Capsicum* in India the plant is almost certainly not indigenous in Asia but has its home in tropical South America where its cultivation is ancient and where it has been found growing wild on the banks of the Amazon and in eastern Peru. De Candolle [1] cites the fact that there is no name for chillies in Sanskrit and Chinese as evidence that this plant was not known to Asia until modern times. Had such a plant been native in the Old World, its cultivation would have spread rapidly and it would have had names in several ancient languages, whereas Greek, Latin, and Hebrew, like Sanskrit and Chinese, do not contain any name for chillies, and the Romans, Greeks, and Hebrews, appear to have been unacquainted with this plant.

The classification of the genus *Capsicum* has been carried out in recent times by Roxburgh,[2] Hooker,[3] Prain,[4] Shrivastava [5] and Irish.[6] The first four authors described the various species of Indian chillies and the last named author worked with a large collection of different forms of *Capsicum* in the Missouri Botanic Garden. Early writers have described a large number of different species opinion varying greatly concerning the number of species and varieties. In a summary of previous systematic work with this genus Irish writes as follows :—

"Three varieties were figured by Fuchsius in 1542, thirteen by Gregorius in 1611, twenty by Parkinson in 1642. Thirty-five were mentioned by Morison in 1699,

[1] De Candolle, Alphonse. Origin of Cultivated Plants. Second Edition, 1904, page 288.
[2] Roxburgh, W. Flora Indica, 1832, Vol. I, page 573.
[3] Hooker, *loc. cit.* page 2.
[4] Prain, *loc. cit.* page 2.
[5] Shrivastava, *loc. cit.* page 4.
[6] Irish, H.C. Revision of Genus Capsicum. *Missouri Bot. Gard. Report* 9, 1898.

twenty-seven by Tournefort in 1700, eighteen by Miller in 1731, though in 1771 after the binomial system had come into use, he gave but ten specific names. Linnaeus in the first edition of his Species Plantarum (1753) records two species and in his Mantissa (1767) recognises two additional ones. In the fourteenth edition of his Systema Vegetabilium, edited by Murray (1789), one new species is given, and in the Willdenow edition of the Species Plantarum (1797) still another is added. Romer and Schultzes in their edition of the Systema Vegetabilium (1819), add what they considered fifteen good and three doubtful species to those already described since the time of Linnaeus. Of these fifteen, only one was given for the first time by them all the others having been previously named by various botanists since Willdenow's edition. In 1832 Fingerhuth recognized twenty-five accepted species, together with seven requiring further examination, and twenty-eight botanical varieties, three of the species and most of the varieties being named by him. In 1846 Sendtner recorded ten species and numerous varieties as occurring in Brazil alone, he having named seven of the species. In 1852, Dunal recorded fifty accepted species, of which eleven were described for the first time, together with many varieties, and eleven species requiring further examination, besides three doubtful ones."

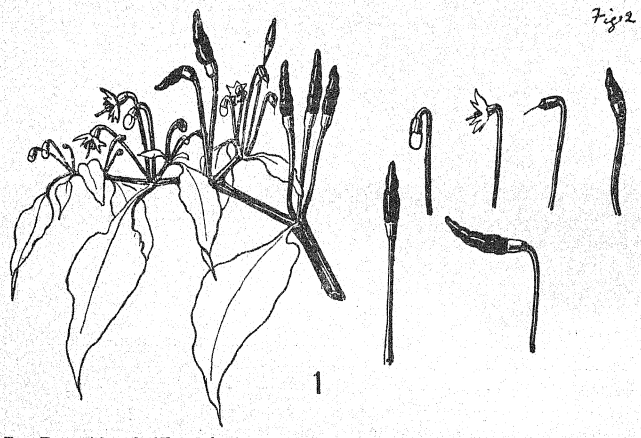
The Index Kewensis recognises fifty-four specific names, out of ninety which have been given, but modern authorities generally consider that there are only a few species in the genus. Roxburgh describes 6 species *C. purpureum* R., *C. annuum* Willd., *C. grossum* Willd., *C. frutescens* Willd., *C. minimum* R., and *C. cerasiforme* Willd. Of these six species the last named, *C. cerasiforme* has globular fruits and *C. minimum* has the peduncles in pairs; the remainder have more or less elongated fruits with solitary peduncles. Hooker reduces the number of Indian species to three—*C. frutescens* Linn., *C. minimum* Roxb., and *C. grossum* Willd. The form *cerasiforme* is given as a variety of *C. grossum* and is stated to be rarely cultivated in India; we have, however, found that it is the predominant chilli of the North-West Frontier Province. Both Irish and Prain still further reduced the number of species to two—*C. annuum* Linn., and *C. frutescens* Linn. The latter species has the peduncles in pairs and is synonymous with the *C. minimum* of Roxburgh and Hooker. The species *C. annuum* Linn. is divided into a number of varieties which include all the other forms, *C. purpureum*, *C. grossum*, *C. cerasiforme*, etc. of Roxburgh and earlier writers. The list of species and varieties described by Irish and Prain is as follows:—

IRISH	PRAIN
C. frutescens.	*C. frutescens.*
C. annuum conoides.	,, ,, var. *Baccata.*
,, ,, *fasciculatum.*	*C. annuum*
,, ,, *acuminatum.*	,, ,, var. *acuminata.*
,, ,, *longum.*	,, ,, ,, *abbreviata.*
,, ,, *abbreviatum.*	,, ,, ,, *grossa.*
,, ,, *cerasiforme.*	,, ,, ,, *cerasiformis.*
,, ,, *grossum.*	,, ,, ,, *nigra.*

(2) *The Differentiating Characters.*

Different authors have attached different degrees of importance to the morphological characters on which the taxonomic divisions of the genus are based. Generally the shape of the fruit and the nature of the calyx are taken as two of the most reliable differentiating characters. The erect or pendent character of the fruit is not a satisfactory criterion for a main taxonomic division within the genus as both types occur within different varieties. The morphological characters used in the present paper for the separation of the various types are as follows :—

1. *Number of pedicels in the axil* (Text Fig. 3, Type 1).



TEXT FIG. 3. A branch of Type 1 showing more than one pedicel in an axil and stages in the development of the erect fruit.

The branching of chillies simulates dichotomy. At the point of branching there is generally a single terminal pedicel bearing a flower bud, but in a few somewhat rare types the pedicels are not solitary, two or even three arising at the same place. This character has been taken as the first main distinction in our classification and serves to separate the species "*frutescens*" from the species "*annuum*." The present writers are in agreement with Prain and Irish in making these the only two species within the genus.

2. *Flower colour.*[1]

Most of the varieties have white or dirty-white flowers, in two types, however, the flowers are greenish-white and in one they are purple or splashed with purple colour.

3. *Shape of the fruit.*[2]

Fruits may be divided into "globular" and "not globular." The latter may be any shape from elongated finger shaped forms to conical irregular forms nearly as broad as they are long. The globular fruited forms are classed by Prain in the variety "*annuum* var. *cerasiformis*" and we have adopted this nomenclature in the case of the globular forms with small fruits. We have, however, found in our collection some large fruited forms in which the fruits although globular can hardly be classed as "cerasiformis." As in these large fruited varieties the surface of the fruit is corrugated we have named them "*annuum* var. *rugosa*." In addition to the division into fruits "globular" and "not globular" Prain further divides the latter group into "berries tapering much longer than broad" and "berries not much if at all longer than broad, usually obtuse." We have not found this a reliable criterion and have not, therefore, used this character at this point in the classification, but at a later stage we have classified fruits as long, medium in length and short.

4. *Nature of the calyx.*

The calyx may or may not enclose the base of the fruit. This character is used by Prain and by Irish and we have found it a good and reliable criterion. In varieties with thin fruits the calyx usually encloses the base of the fruit like a cup but in forms with thick fruits the base of the fruit is generally broader than the span of the calyx which therefore forms a flat green disc at the base of the fruit. In rare cases when the diameter of the calyx is about equal to that of the base of the fruit it is difficult to decide whether the calyx is slightly enclosing the base of the fruit or not; in such doubtful cases an examination of the largest fruits on the plant will always show that the calyx is really not enclosing the base of the fruit.

The four characters mentioned above furnish the basis on which the separation of the different types is made; all have been used by previous authors and the system followed in this paper agrees very closely with that used by Prain.

5. *Shape of transverse section of the fruit.*

The transverse section of the fruit may be circular, quadrate, corrugated, or irregularly angular.

6. *Position of the fruit.*[3]

As previously described (page 60) fruits may be either pendent or erect. In some erect varieties in which the fruits are very heavy, the fruits tend to assume a

[1] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 243.
[2] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 244.
[3] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 289.

horizontal position (Text Fig. 1, Type 22) when mature; the true erect nature of such fruits can be seen from inspection of the younger fruits. The erect or pendent position of the fruit is a good distinguishing character, but it cannot be used very early in the classification as erect and pendent fruited types can be found in many varieties.

7. *Colour of the fruit.*

The colour [1, 2] of the mature fruit is either red or orange but that of the immature fruit may be white, light green, green, dark green or purple. The majority of fruits are some shade of green when young and in a number of the types the green becomes marked with purple as the fruit develops. The amount of purple which is developed varies considerably in different types, it is generally most marked on the side of the fruit which is towards the sun. In one of our varieties (*C. annuum* var. *nigra*) the immature fruit is entirely purple, and indeed in this type the purple colour is spread over the whole plant; the fruit, however, is red when mature. In all types the purple colour changes more or less to green again as the fruit approaches maturity finally becoming red or orange coloured when ripe. The presence or absence of purple colour in the fruit, and the degree of its development, has been found a useful minor differentiating character.

The ripe fruit is either red or orange and the two colours are easily distinguished one from the other. There are of course several grades of each colour and these are difficult to distinguish, particularly in the case of old and completely mature fruits in which the colour deepens considerably with exposure to the sun.

8. *Size of the fruit.*

The ratio of length to breadth in the fruit was not found by us to be a useful differentiating character and as a point of minor distinction we have classified fruits as short (up to 4 cm. long), medium (from 4 to 7 cm. long) and long (above 7 cm.).

9. *Surface of the fruit.*

The surface of the fruit is generally smooth in the fresh state but in all fruits a certain amount of shrinkage, and resulting wrinkling of the surface, takes on drying. In some types, however, depressions occur even in the fresh state and in the case of long thin fruits this wrinkled character has been found useful in separating minor types.

10. *Apex of the fruit.*

The apex of the fruit is pointed (acute) in some types and blunt in others. In a few special cases (Types 14, 15, 16 and 17) it is more or less lobed with a depression in the centre.

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[1] Halsted, Byron, D. Colors in Vegetable Fruits. *Jour. of Heredity*, Vol. IX, page 22, 1918.
[2] *New Jersey Agri. Coll. Expt. Sta. Bot. Dept. Report* 1910, page 246.

11. *Flesh of the fruit.*

The inner portion of the wall of the fruit, beneath the skin, is called the flesh. In some types the flesh is very thin, and in others it is very thick, the two kinds can be easily distinguished and this has been used as a differentiating character by some writers; it is not so used in this paper.

12. *Maturity.*

Types are classed as early, intermediate, late and very late.

13. *Colour of the foliage.*

The different types vary as regards the greenness of their foliage; we have classified them as dark green, green and light green.

14. *Height of the plant.*

Types having a height of less than 40 cm. have been classed as short, from 40 to 60 cm. have been classed as medium in height, and above 60 cm. have been called tall.

15. *Character of the stem.*[1]

The stem is angular when young becoming circular in cross section as it gets older. The colour is at first green which becomes streaked with grey as cork is formed; in some varieties small patches of purple colour are developed in the stem particularly in the axils of branches and leaves. Irish states that the species *frutescens* and *cerasiforme* have stems which are much swollen at the node but the forms which we have classified as *frutescens* are scarcely swollen at all and forms which we have placed in *cerasiforme* are only slightly swollen. Almost all our types show some degree of swelling at the node, but we do not consider that this character affords a sound differentiating basis and we have not used it.

(3) *Key to the Types of Capsicum.*

Pedicels 2 or more (*C. frutescens*)—
- Unripe fruits green . . . . . Type 1
- Unripe fruits white . . . . . Type 2

Pedicels solitary (*C. annuum*)—
- Flowers purple (*C. annuum* var. *nigra*) . . . . . Type 3
- Flowers white.
  - Fruits globular, large, irregular in transverse section, pendent (*C. annuum* var. *rugosa*)—
    - Fruits completely corrugated, broader than long, apex very broad . . Type 4
    - Fruits corrugated at base only, medium in size, flattened at top with distinct depression at the base of style, broader than long . . . . Type 5
  - Fruits globular, small, circular in transverse section (*C. annuum* var. *cerasiformis*)—
    - Fruits pendent, red, small, not corrugated, hard, symmetrically globular, breadth equal to length (*C. annuum* .var *cerasiformis pendula*)—
      - Leaves light green . . . . . Type 6
      - Leaves green . . . . . Type 7
    - Fruits erect, orange, small, with distinct apical point (*C. annuum* var. *cerasiformis erecta*) . . . . . Type 8

[1] *New Jersey Agri. Coll. Expt. Stu. Bot. Dept. Report* 1910, page 242

- Fruits elongated—
  - Calyx not embracing the base, fruits generally broad—
    - Fruits circular in transverse section—
      - Fruits short (up to 4 cm.) (*C. annuum* var. *abbreviata*)—
        - Fruit apex acute, leaves dark green . . . . . Type 9
        - Fruit apex blunt, leaves light green . . . . . Type 10
      - Fruits medium in length (from 4 to 7 cm.) (*C. annuum* var. *intermedia*) . Type 11
      - Fruits long (above 7 cm.) (*C. annuum* var. *longa*)—
        - Fruits slightly purple before maturity, smooth . . . Type 12
        - Fruits not purple before maturity, rough surfaced . . Type 13
    - Fruits not circular in transverse section—
      - Fruits angular or irregular in transverse section (*C. annuum* var. *grossa*)—
        - Fruits orange yellow when ripe . . . . . Type 14
        - Fruits red when ripe—
          - Fruits not purple before maturity—
            - Plants short . . . . . Type 15
            - Plants tall . . . . . Type 16
          - Fruits slightly purple before maturity . . . Type 17
      - Fruits quadrate in transverse section (*C. annuum* var. *quadrata*)—
        - Fruits short in length—
          - Leaves light green, plants early . . . . . Type 18
          - Leaves dark green, plants intermediate in maturity . Type 19
        - Fruits medium in length . . . . . Type 20
  - Calyx embracing the base, circular in transverse section—
    - Fruits erect (*C. annuum* var. *acuminata erecta*)—
      - Fruit orange . . . . . Type 21
      - Fruit red . . . . . Type 22
    - Fruits pendent (*C. annuum* var. *acuminata pendula*)—
      - Fruit orange—
        - Fruit short in length . . . . . Type 23
        - Fruit medium in length—
          - Leaves light green, plants spreading . . . Type 24
          - Leaves dark green, plants erect . . . . Type 25
        - Fruit long—
          - Leaves very light green—
            - Plants early . . . . . Type 26
            - Plants late . . . . . Type 27
          - Leaves dark green—
            - Fruits not purple before maturity . . Type 28
            - Fruits moderately purple before maturity . Type 29
      - Fruits red—
        - Fruits short in length—
          - Leaves light green, plants spreading . . . Type 30
          - Leaves green, plants tall . . . . . Type 31
          - Leaves dark green—
            - Plants spreading, early . . . . Type 32
            - Plants erect, tall, intermediate in maturity . Type 33
        - Fruits medium in length—
          - Leaves light green, fruit moderately purple before maturity Type 34
          - Leaves green, fruit not purple before maturity . Type 35
          - Leaves dark green, fruit with much purple colour before maturity—
            - Plants early, spreading . . . . . Type 36
            - Plants late, erect . . . . . Type 37
        - Fruits long—
          - Fruit not wrinkled—
            - Fruits not purple before maturity, leaves light green . . . . . Type 38
            - Fruits moderately purple before maturity, leaves green . . . . . Type 39

Fruits long—*contd.*
Fruits not wrinkled—*contd.*
Fruits with much purple colour before maturity—
Leaves green . . . . . Type 40
Leaves dark green. . . . . Type 41
Fruits wrinkled—
Fruits not purple before maturity—
Leaves light green—
Plants very late . . . . . Type 42
Plants intermediate in maturity . . Type 43
Leaves green . . . . . Type 44
Leaves dark green. . . . . Type 45
Fruits moderately purple before maturity—
Plants early . . . . . Type 46
Plants intermediate in maturity . . Type 47
Plants late in maturity . . . . Type 48
Fruits with much purple colour before maturity—
Leaves light green . . . . . Type 49
Leaves green . . . . . Type 50
Leaves dark green—
Plants early . . . . . Type 51
Plants late . . . . . Type 52

Statement showing the origin of the seed from which cultures were grown for the isolation of the types.

Place	District	Province	Type No. 1928-29.
Peshawar	Peshawar . .	N. W. Frontier .	6
,, ...	,, . .	,, .	7
Lahore	Lahore . .	Punjab . .	32
Saharanpur	Saharanpur . .	U. P. . . .	8
,, ...	,, . .	,, . . .	23
,, ...	,, . .	,, . . .	31
,, ...	,, . .	,, . . .	10
Pusa Farm	Darbhanga . .	Bihar and Orissa .	3
,, ...	,, . .	,, .	4
,, ...	,, . .	,, .	13
,, ...	,, . .	,, .	41
Cuttack	Cuttack . .	,, .	22
,, ...	,, . .	,, . .	46
Birbhum	Birbhum . .	Bengal . . .	21
,, ...	,, . .	,, . . .	24
,, ...	,, . .	,, . . .	30

Statement showing the origin of the seed from which cultures were grown for the isolation of the types—contd.

Place	District	Province	Type No. 1928-29
Faridpur	Faridpur	Bengal	25
,,	,,	,,	28
Jessore	Jessore	,,	26
,,	,,	,,	29
Berhampur	Berhampur	,,	38
Howrah	Howrah	,,	40
Comilla	Tipera	,,	35
,,	,,	,,	39
,,	,,	,,	43
,,	,,	,,	51
Sutton's Mammoth Long Red	....	....	15
Sutton's Colossal	....	....	14
Sutton's Spanish Giant	....	....	17
Jorhat	Sibsagar	Assam	34
Surma Valley	,,	,,	36
,, ,,	,,	,,	37
Nadiad	Kaira	Bombay	44
	,,	,,	50
,,	,,	,,	52
Ahmedabad	Ahmedabad	,,	33
,,	,,	,,	45
,,	,,	,,	48
Bail Hongal	Belgaum	,,	49
Gadag	Dharwar	,,	42
,,	,,	,,	47
Kumpta	Kanara	,,	9
Malabar	Malabar	Madras	1

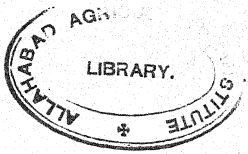
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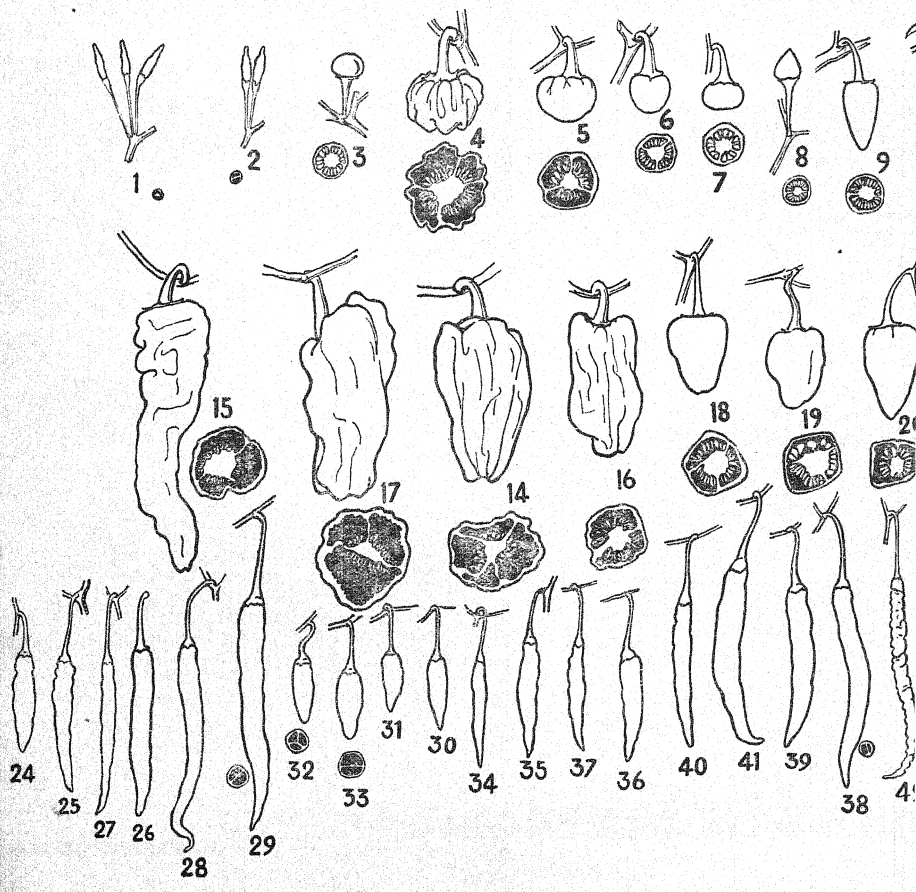
PLATE I.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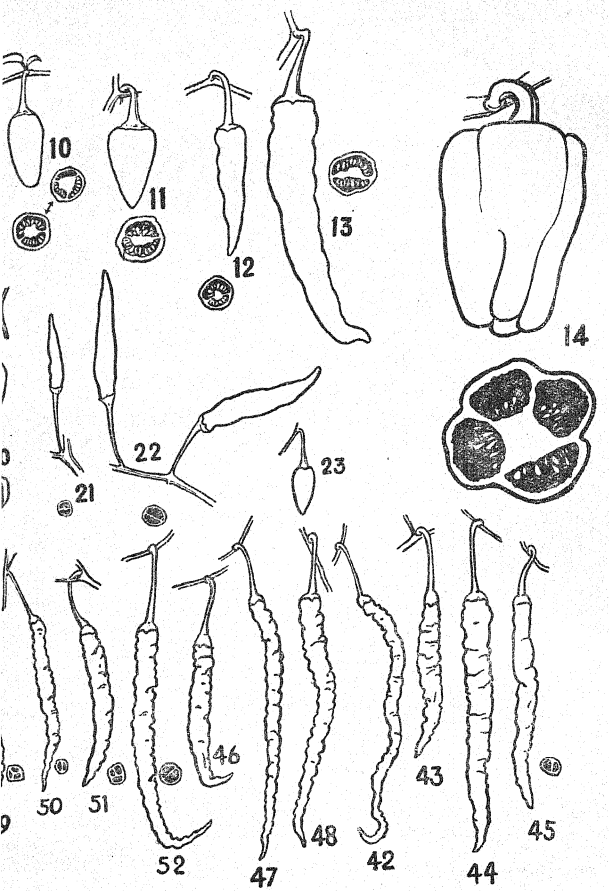
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Statement showing the origin of the seed from which cultures were grown for the isolation of the types—concld.

Place	District	Province	Type No. 1928-29
Malabar	Malabar	Madras	2
Coimbatore	Coimbatore	,,	16
Ganjam	Ganjam	,,	27
Meiktila	Meiktila	Burma	5
,,	,,	,,	18
,,	,,	,,	19
,,	,,	,,	20
Allanmyo	Thayetmyo	,,	11
,,	,,	,,	12

IV. Description of the types.

The fruits of all types are illustrated on Plate I.

Type 1. Plants tall (76 cm.), very late, prolific, perennial ; leaf 12·0 cm.×5·8 cm., green ; flowers 2 or more in the axil ; pedicel longer than the fruit ; corolla greenish white ; calyx enclosing the base of the fruit ; style white ; fruit short, 1·8 cm. × 0·3 cm., two celled, elongated, circular in transverse section, erect or sub-erect, unripe green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·12 gram. A very pungent form.

This type agrees with the species *C. frutescens* of Irish.

Type 2. Plants tall (73 cm.), late, prolific, perennial ; leaf 7·0 cm.×4·2 cm., yellowish green ; flowers 2 or more in the axil ; pedicels longer than the fruit ; corolla greenish white ; calyx enclosing the base of the fruit ; style white, fruit short, 1·8 cm.×0·3 cm., two celled, elongated, circular in transverse section, erect or sub-erect, unripe white without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·12 gram. A very pungent form.

This type agrees with the *C. frutescens* of Irish.

Type 3. Plants tall (66·0 cm.), intermediate in maturity, poor in bearing, annual ; leaf 8·5 cm.×4·2 cm., purple ; flower one in the axil ; pedicel nearly equal to the fruit ; corolla purple ; calyx not enclosing the base of the fruit ; style purple ; stigma purple ; fruit short, globular, 1·2 cm. ×1·4 cm., 3 celled, circular in transverse section, erect, unripe purple becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit 0·98 gram (see Plate III).

This type does not agree exactly with any of the types described by Irish ; it shows, however, similarity with the form " Black Nubian " (Irish page 76).

Type 4. Plants tall (72 cm.), intermediate in maturity, moderate in bearing, annual ; leaf 9·6 cm.×5·2 cm., dark green ; flower one in the axil ; pedicel nearly equal to the fruit ; corolla white ; calyx not enclosing the base of the fruit ; style white ; fruit short, swollen, completely corrugated, broader than long, globular, 3·0 cm.×4·0 cm., 3 to 4 celled, irregular in transverse section, pendent, unripe green with much purple colour, becoming red when mature, apex blunt, very broad, flesh thick, average weight of a fresh ripe fruit 5·6 grams (see Plate IV).

This type resembles the form Squash (Irish, page 87).

Type 5. Plants tall (61 cm.), intermediate in maturity, prolific, annual ; leaf 9·1 cm.×4·8 cm., dark green ; flower one in the axil ; pedicel nearly equal to the fruit ; corolla white ; calyx not enclosing the base of the fruit ; style white ; fruit short, 2·4 cm.×2·8 cm., 3 celled, globular, irregular in transverse section, corrugated at base, broader than long, pendent, unripe dark green without any purple colour, becoming red when mature, apex blunt with distinct depression at the base of style, flesh thick, average weight of a fresh ripe fruit 5·3 grams.

This type is not described by Irish.

Type 6. Plants medium in height (57 cm.), early, moderate in bearing, annual ; leaf 12·0 cm.×5·2 cm., light green ; flower one in the axil ; pedicel nearly equal to the fruit ; corolla white ; calyx not enclosing the base of the fruit ; style white ; fruit short, 2·0 cm.×1·8 cm., 3 celled, symmetrically globular, circular in transverse section, not corrugated, hard, pendent, unripe light green with moderate purple colour, becoming red when mature, apex blunt, flesh rather thick, average weight of a fresh ripe fruit 2·3 grams.

This type resembles the form Cherry described by Irish (page 93).

Type 7. Plants medium in height (47 cm.), early, moderate in bearing, annual ; leaf 8·5 cm.×3·5 cm., green ; flower one in the axil ; pedicel nearly equal to the fruit ; corolla white ; calyx not enclosing the base of the fruit ; style white ; fruit short, 1·7 cm.×1·9 cm., 3 celled, symmetrically globular, circular in transverse section, not corrugated, pendent, unripe light green with slight purple colour, becoming red when mature, apex blunt, flesh rather thick, average weight of a fresh ripe fruit 2·6 grams.

This type resembles the form Cherry (Irish, page 93).

Type 8. Plants tall (62 cm.), early, moderate in bearing, annual ; leaf 8·5 cm. ×4·1 cm., light green ; flower one in the axil ; pedicel nearly equal to the fruit ; corolla white ; calyx not enclosing the base of the fruit ; style white ; fruit short, 1·5 cm.×1·1 cm., 2 to 3 celled, globular, with distinct apical point, circular in transverse section, erect, unripe light green with much purple colour, orange when mature, flesh thin, average weight of a fresh ripe fruit 0·74 gram (see Plate II).

This type was isolated from a culture which was splitting into forms with red and yellow and erect and pendent fruits.

It may resemble the form Prince of Wales described by Irish (page 93); it is not however stated by Irish whether this form has erect fruits.

Type 9. Plants medium in height (46 cm.), early, moderate in bearing, annual; leaf 9·5 cm.×4·5 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 3·5 cm.×1·7 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thick, average weight of a fresh ripe fruit 2·6 grams.

This type is not described by Irish.

Type 10. Plants medium in height (58 cm.), intermediate in maturity, moderate in bearing, annual; leaf 8·5 cm.×4·5 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 3·7 cm.×1·7 cm., 2 to 3 celled, elongated, circular in transverse section, pendent, unripe green with a slight purple colour, becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit 3·4 grams.

This type is not described by Irish.

Type 11. Plants tall (70·0 cm.), intermediate in maturity, poor in bearing, annual; leaf 8·0 cm.×3·9 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit medium in length, 4·2 cm.×2·4 cm., 2 celled, elongated, more or less conical, circular in transverse section, pendent, unripe dark green without any purple colour, becoming red when mature, apex acute, flesh thick, average weight of a fresh ripe fruit 4·6 grams.

This type is not described by Irish.

Type 12. Plants tall (62·0 cm.), early, prolific, annual; leaf 8·0 cm.×3·5 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 7·5 cm.×1·6 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with a slight purple colour, becoming red when mature, apex acute, flesh thick, surface smooth, average weight of a fresh ripe fruit 4·1 grams.

This type is not described by Irish. It was isolated from a culture which was splitting as regards the size of its fruits.

Type 13. Plants medium in height (57·0 cm.), early, moderate in bearing, annual; leaf 9·1 cm.×4·1 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 13·0 cm.×2·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thick, surface rough, average weight of a fresh ripe fruit 7·5 grams.

This type resembles the form Cardinal (Irish, page 78).

Type 14. Plants medium in height (50·0 cm.), very late, very poor in bearing, annual; leaf 10·5 cm.×5·0 cm., green; flower one in the axil; pedicel shorter than

the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 10·0 cm.×7·0 cm., 4 celled, elongated, angular in transverse section, pendent, unripe dark green with no purple colour, becoming orange yellow when mature, apex blunt and lobed, flesh thick, average weight of a fresh ripe fruit 37 grams.

This culture was obtained from Messrs. Sutton and Sons (Calcutta) under the name of Colossal and according to their catalogue [1] has red fruits. The type as isolated by us, however, has orange yellow fruits and resembles the form Yellow Spanish of Irish.

Type 15. Plants short (37·0 cm.), intermediate in maturity, poor in bearing, annual; leaf 9·2 cm.×5·1 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 13·5 cm.×3·5 cm., 3 celled, elongated, circular in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex acute, sometimes lobed, flesh thick, average weight of a fresh ripe fruit 19·0 grams.

This type was received from Messrs. Sutton & Sons (Calcutta), with the name Mammoth Long Red. It resembles the form Elephant's Trunk described by Irish (page 80).

Type 16. Plants very tall (78·0 cm.), very late, very poor in bearing, annual; leaf 7·4 cm.×4·1 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit medium in length, 6·0 cm.×2·5 cm., 2-3 celled, elongated, angular in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex blunt and lobed, flesh thick, average weight of a fresh ripe fruit 3·6 grams.

This type resembles the form Sweet Spanish of Irish (page 83-4).

Type 17. Plants tall (72·0 cm.), late, very poor in bearing, annual; leaf 8·0 cm.×3·8 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit long, 10·3 cm.×5·0 cm., 3-4 celled, elongated, angular in transverse section, pendent, unripe dark green with a slight purple colour, becoming red when mature, apex blunt and lobed, flesh thick, average weight of a fresh ripe fruit 67 grams (see Plate V).

This culture was received from Messrs. Sutton & Sons (Calcutta), with the name Spanish Giant. It resembles the form Sweet Spanish of Irish (page 83—4).

Type 18. Plants tall (62·0 cm.), early, prolific, annual; leaf 9·0 cm.×4·6 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short 4·0 cm.×3·0 cm., 3 celled, elongated, quadrate in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit 11·4 grams.

This type is not described by Irish.

[1] Sutton's Garden Seeds, 1927.

Type 19. Plants medium in height (60·0 cm.), intermediate in maturity, prolific, annual; leaf 8·5 cm.×4·6 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit short, 3·9 cm.×3·0 cm., 3 celled, elongated, quadrate in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit, 7·9 grams.

This type is not described by Irish.

Type 20. Plants tall (70·0 cm.), early, moderate in bearing, annual; leaf 7·5 cm.×3·5 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx not enclosing the base of the fruit; style white; fruit medium in length, 4·8 cm.×2·6 cm., 2-3 celled, elongated, somewhat conical in shape, quadrate in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex acute, flesh thick, average weight of a fresh ripe fruit 6·0 grams.

This type is not described by Irish.

Type 21. Plants medium in height (57·0 cm.), late, moderate in bearing, annual; leaf 7·0 cm.×3·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 4·0 cm.×0·7 cm., 2 celled, elongated, circular in transverse section, erect, unripe light green with much purple colour becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·93 grams.

This type resembles the Yellow Chilli of Irish (page 71).

Type 22. Plants very tall (80·0 cm.), early, prolific, annual; leaf 13·0 cm.×6·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white,; fruit medium in length, 6·4 cm.×1·0 cm., elongated, circular in transverse section, erect, unripe dark green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·85 grams.

This type resembles the Chilli of Irish (page 70).

Type 23. Plants short (34·0 cm.), very early, moderate in bearing, annual; leaf 5·6 cm.×3·0 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx almost enclosing the base of the fruit; style white; fruit short, 2·7 cm.×1·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with slight purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 0·87 grams.

This type resembles the Yellow Nepal of Irish (page 73).

Type 24. Plants spreading, tall (63·0 cm.), very early, prolific, annual; leaf 10·5 cm.×5·0 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit medium in length, 5·0 cm.× 1·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·4 grams.

This type is not described by Irish.

Type 25. Plants erect, very tall (73·0 cm.), early, prolific, annual; leaf 10·0 cm.×5·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit medium in length, 7·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with moderate purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·7 grams.

This type is not described by Irish.

Type 26. Plants medium in height (54·0 cm.), early, prolific, annual; leaf 9·5 cm.× 4·2 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx almost enclosing the base of the fruit; style purple; fruit long, 8·4 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with much purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 4·0 grams.

This type is not described by Irish.

Type 27. Plants medium in height (54·0 cm.), late, prolific, annual; leaf 8·8 cm.×3·8 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·2 cm. ×0·7 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·8 grams.

Type 28. Plants medium in height (53·0 cm.), early, prolific, annual; leaf 9·0 cm.×3·7 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green without any purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·8 grams.

Type 29. Plants very tall (83·0 cm.), late, prolific, annual; leaf 13·0 cm.×6·0 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style purple; fruit long, 12·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with moderate purple colour, becoming orange when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 5·5 grams (see Plate II).

This type and the two preceding types, 27 and 28, resemble the Long Yellow Cayenne of Irish (page 72-73).

Type 30. Plants spreading, medium in height (48·0 cm.), late, poor in bearing, annual; leaf 8·5 cm.×3·5 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 4·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming red when mature, apex blunt, flesh thin, average weight of a fresh ripe fruit 1·6 grams.

Type 31. Plants spreading, tall (69·0 cm.), early, moderate in bearing, annual; leaf 9·5 cm.×4·6 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 3·0 cm.×1·1 cm., 2-3 celled, elongated, circular in transverse section, pendent, unripe light green with moderate purple colour becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·3 grams.

Type 32. Plants spreading, medium in height (49·0 cm.), early, moderate in bearing, annual; leaf 10·5 cm.×4·7 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit short, 3·3 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, pendent, unripe light green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·4 grams.

Type 33. Plants erect, medium in height (60·0 cm.), intermediate in maturity, prolific, annual; leaf 10·3 cm.×4·9 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx almost enclosing the base of the fruit; style purple; fruit short, 3·5 cm.×1·2 cm., 2 celled, elongated, circular in transverse section, pendent, unripe dark green with much purple colour, becoming red when mature, apex acute, flesh rather thick, average weight of a fresh ripe fruit 2·2 grams.

This type and types 30, 31, 32, resemble the Nepal Chilli of Irish (page 73).

Type 34. Plants tall (63·0 cm.), very early, very prolific, annual; leaf 10·6 cm.×4·6 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style purple; fruit medium in length, 5·7 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·4 grams.

Type 35. Plants medium in height (57·0 cm.), early, moderate in bearing, annual; leaf 7·5 cm.×4·2 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit medium in length, 6·2 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·9 grams.

Type 36. Plants spreading, medium in height (52·0 cm.), early, prolific, annual; leaf 9·5 cm.×4·6 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style purple; fruit medium in length, 5·6 cm.×1·3 cm., 2 celled, elongated, circular in transverse section, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·4 grams.

Type 37. Plants erect, medium in height (50·0 cm.), late, poor in bearing, annual; leaf 7·0 cm.×2·8 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style purple; fruit medium in length, 5·7 cm.×0·8 cm., 2 celled, elongated, circular in transverse

section, pendent, unripe dark green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·6 grams.

This type and types 34, 35, 36 do not appear to be described by Irish.

Type 38. Plants medium in height (60·0 cm.), late, prolific, annual; leaf 9·8 cm.×4·3 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·8 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·5 grams.

Type 39. Plants tall (68·0 cm.), late, prolific, annual; leaf 10·0 cm.×4·5 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·3 cm.×1·1 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe light green with slight purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·9 grams (see Plate III).

Type 40. Plants medium in height (55·0 cm.), intermediate in maturity, moderate in bearing, annual; leaf 9·0 cm.×3·8 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 7·8 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·0 grams.

Type 41. Plants tall (61·0 cm.), early, very prolific, annual; leaf 12·5 cm.×5·2 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 9·4 cm.×1·1 cm., 2 celled, elongated, circular in transverse section, not wrinkled, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 5·0 grams.

This type and types 38, 39, 40 resemble the long Cayenne of Irish (page 71).

Type 42. Plants medium in height (51·0 cm.), very late, poor in bearing, annual; leaf 7·0 cm.×2·8 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·0 cm.×0·7 cm., 2-3 celled, elongated, circular in transverse section, wrinkled, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·3 grams.

Type 43. Plants medium in height (41·0 cm.), intermediate in maturity, poor in bearing, annual; leaf 10·1 cm.×5·1 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·2 cm.×1·1 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 1·4 grams.

Type 44. Plants medium in height (50·0 cm.), very late, poor in bearing, annual; leaf 11·0 cm.×5·5 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·3 cm.×1·2 cm., 3 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 4·2 grams.

Type 45. Plants medium in height (60·0 cm.), intermediate in maturity, very prolific, annual; leaf 10·9 cm.×4·3 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·5 cm.×1·0 cm., 2 celled, elongated, circular in transverse section wrinkled, pendent, unripe light green without any purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 4·5 grams.

Type 46. Plants medium in height (52·0 cm.), early, prolific, annual; leaf 12·5 cm.×4·8 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla, white; calyx enclosing the base of the fruit; style white; fruit long, 8·9 cm.×1·1 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe fruit green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·6 grams.

Type 47. Plants medium in height (60·0 cm.), intermediate in maturity, moderate in bearing, annual; leaf 8·0 cm.×3·5 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·5 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·1 grams.

Type 48. Plants tall (68·0 cm.), late, very prolific, annual; leaf 11·9 cm. ×6·1 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 13·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green with moderate purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 5·1 grams.

Type 49. Plants medium in height (57·0 cm.), very late, poor in bearing, annual; leaf 9·8 cm.×4·2 cm., light green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 10·5 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·1 grams.

Type 50. Plants medium in height (57·0 cm.), late, moderate in bearing, annual; leaf 11·0 cm.×5·0 cm., green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 9·0 cm.×0·8 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent,

unripe green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 2·2 grams.

Type 51. Plants tall (67·0 cm.), early, very prolific, annual; leaf 11·3 cm.×5·5 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 8·2 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe light green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·9 grams.

Type 52. Plants tall (66·0 cm.), very late, prolific, annual; leaf 13·5 cm. ×6·2 cm., dark green; flower one in the axil; pedicel shorter than the fruit; corolla white; calyx enclosing the base of the fruit; style white; fruit long, 12·0 cm.×1·0 cm., 2 celled, elongated, circular in transverse section, wrinkled, pendent, unripe light green with much purple colour, becoming red when mature, apex acute, flesh thin, average weight of a fresh ripe fruit 3·8 grams.

This type and types 42 to 51, are not described by Irish.

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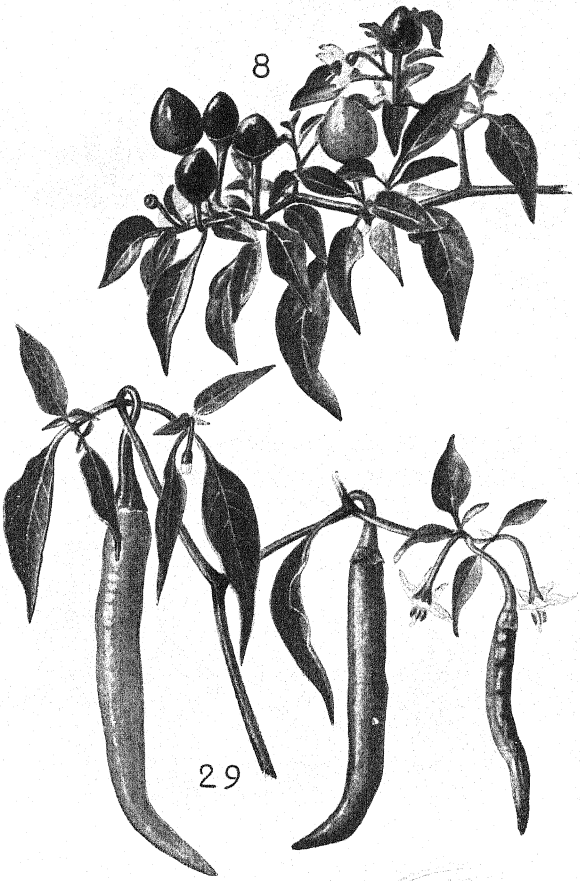

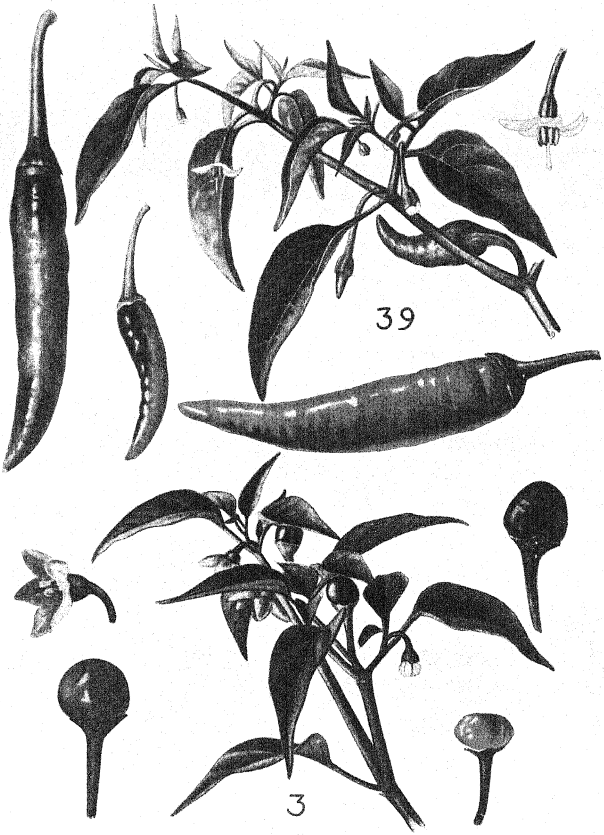
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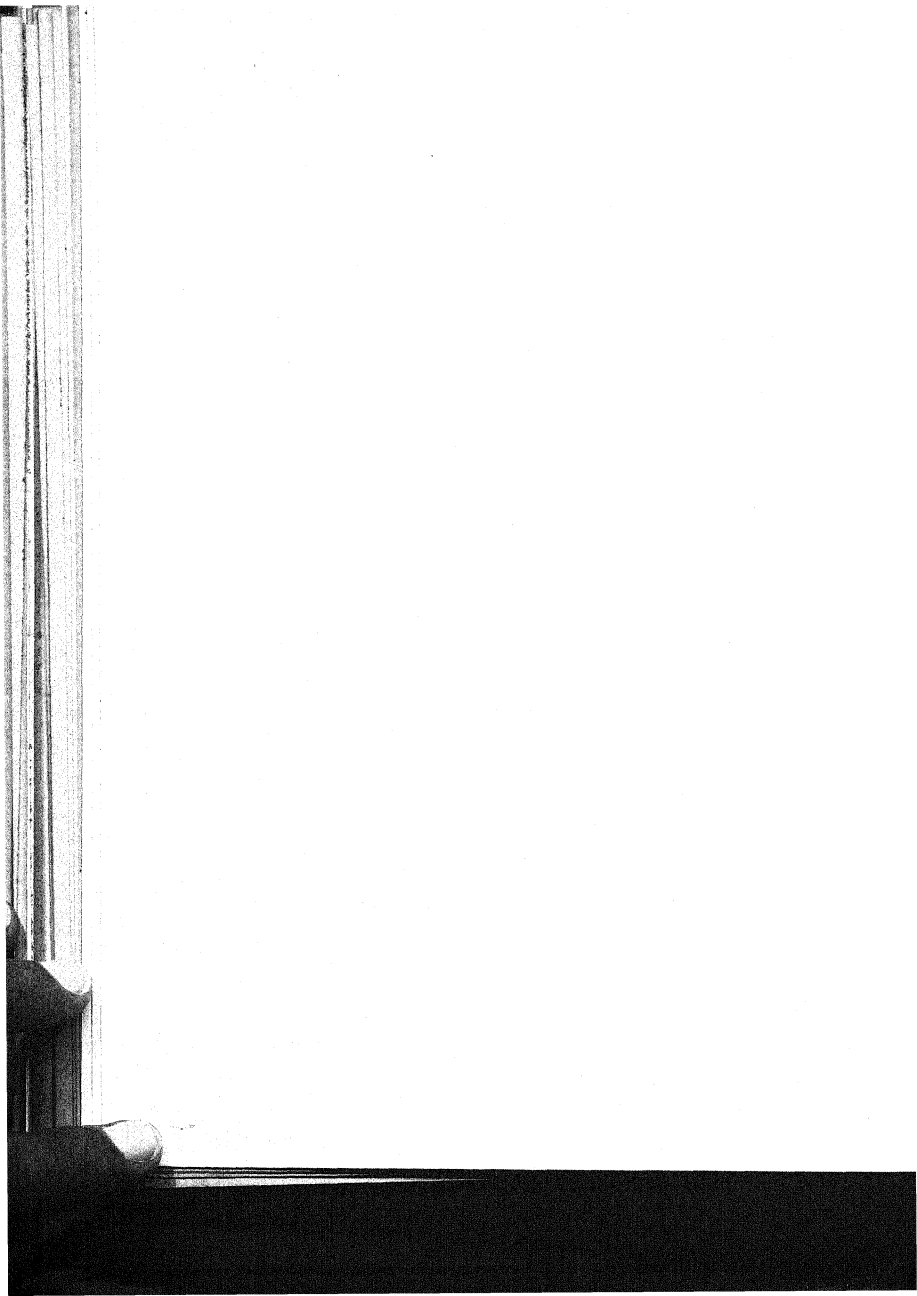


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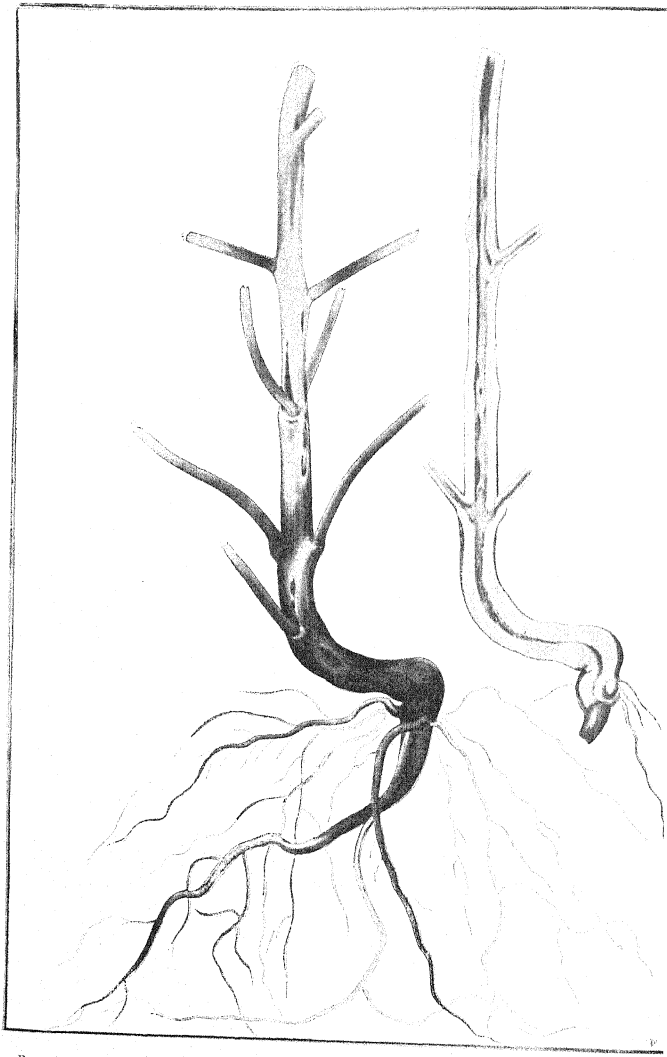

Base of stem with roots of a diseased Antirrhinum plant. The bark has rotted and fallen off. Diseased roots are blackened. By the side is the same cut open to show the mycelial wefts in the hollowed pith region.

FOOT-ROT AND WILT OF ANTIRRHINUMS

Caused by

Phytophthora pini var. *antirrhini*, n. v.

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Antirrhinums (snapdragons) belong to the natural order Scrophularineae and by virtue of their beautiful and showy flowers form favourite ornamental plants for gardens. The varieties that are generally grown are forms of *Antirrhinum majus*. Though hardy and perennial by nature, they are generally cultivated as annuals since the first crop of bloom is usually the one which is desired. They grow anywhere but thrive better in a cool climate. In south India the seeds are sown any time from September to end of November and flowers come out from March to April. If the shoots are pruned off, the ratoon crop will flower again in August or September.

Several fungi have been known to attack antirrhinums. *Sclerotinia sclerotiorum* [1] has been reported to cause considerable damage to the flowers resulting in failure to produce seeds. "The blossoms are killed from the oldest flower upwards and subsequently the stem dies downwards and the lateral branches become similarly affected." Beweley [2] records a wilt of antirrhinum caused by *Verticillium*

[1] Dowson, W. H. A flower spike disease of cultivated Antirrhinums. Abstract, *Review of Applied Mycology*, Vol. III, p. 580.

[2] Bewley, W. F. Report of the Mycologist. Seventh Annual Report Chestnut experiment and Research Station, Hertfordshire. Abstract, *Review of Applied Mycology*, Vol. I, p. 94.

alboatrum. *Phyllosticta antirrhinum* [1] causes a stem-rot and leaf-spot. Two leaf diseases [2] caused by *Cercospora antirrhini* and *Septoria antirrhini* have been observed to result in serious damage to the plants. A rust of antirrhinum [3] caused by *Puccinia antirrhini* is prevalent in Canada and California. Brittlebank and Fish [4] report a wilt of antirrhinums in Victoria caused by *Phytophthora cryptogea*. This has been recorded by Bewley [5] in England.

In the year 1921 antirrhinums in the Botanical Garden at Ootacamund were reported to be damaged by a disease. The plants were found to wilt and die just before they blossomed. The leaves were drooping and the entire plant had the appearance of suffering from drought. The same disease has been observed every year in the Botanic Gardens at Ootacamund and in Sim's Park, Coonoor. Some of the plants in the pot culture house of the Government Mycologist, Coimbatore, were also affected by the same disease, in 1922.

The disease generally appears about the commencement of flowering. Sometimes young plants are also affected. In Sim's Park, Coonoor, it was noticed that the disease appeared in all stages of the plant after transplantation. One by one, the plants in a bed succumb till nearly 50 per cent. of the plants die. In the Botanical Garden at Ootacamund it was observed throughout all antirrhinum plots irrespective of the varieties grown. The disease is virulent during the wet months being absent or rare in dry seasons. It becomes evident on the resumption of fine weather after a prolonged period of rainy days.

The first outward symptom of the disease is the drooping of the leaves and the consequent water-starved appearance of the plant; the collar is rotten and the bark easily comes off. Often the roots are also affected and the cortical region easily separates from the central fibrovascular cylinder. In some instances the rotting is found to be confined to the collar region alone leaving the roots healthy. Rarely it was observed that one portion of the plant is diseased, while the other portions are green and healthy. The wood in the collar region is discoloured having a water soaked and brownish colour or may even be blackened. The leaves wither and get dry. But during rains the leaves of the affected plant become soaked with water, appear dark green and rot, due to the action of the various saprophytic fungi. Examination of the diseased plants invariably reveals the presence of a Phytophthora in the tissues at the affected portions. Oospores of the fungus have been found in

[1] Buddin, W., and Wakefield, E. M. Notes on some antirrhinum diseases. Gardener's chronicle, 1966, pp. 150-152. 1924. Abstract, *Review of Applied Mycology*, Vol. IV, p. 94.

[2] Mains, E. B. Notes on the life history of the snapdragon rust. Puccinia antirrhini Diet and Holo. *Phytophthology*, Vol. XIV, pp. 281-287. Abstract, *Review of Applied Mycology*, Vol. III, p. 721.

[3] Dickson, B. T. Plant diseases of 1920-21. Thirteenth annual report Quebec Society for the protection of plants, pp. 66-67. 1921. Abstract, *Review of Applied Mycology*, Vol. I, p. 374.

[4] Brittlebank, C. C., and Fish, S. A garden fungus disease. A wilt of tomatoes, Iceland poppies, and other garden plants in Victoria caused by the fungus *Phytophthora cryptogea* Peth and Laf. Abstract *in Review of Applied Mycology*, Vol. VI, p. 669.

[5] Bewley, W. F. Damping off and foot-rot of Tomato seedings. *Annals of Applied Biology*, Vol. VII, p. 159.

plenty in the diseased bark as well as within the diseased tissues, in the vessels, etc. A few sporangia were observed on a few diseased plants. The mycelium of the fungus permeates the bark, the cortex and the wood and extends into the pith as well. It can be noticed as cottony tufts inside the hollowed out central portions at the base. The mycelium is both inter and intracellular. In the latter case, it can be seen forcing its way through the cellwalls, the hyphae being constricted just where they pass through the partitions. Long and continuous hyphae are observed in the vessels. No haustoria have been observed. Hyphae have been noticed in plenty in the roots (where they are affected) and in the lower portions of the stem; they have not been observed to extend higher in the stem. Eelworms follow in the wake of the fungus and are present in numbers in badly rotting portions of the host plant.

Great difficulty was experienced in bringing the fungus into pure culture. As the sporangia were few and could not be easily separated from the mud and soil particles with which they were mixed up it was not possible to get the fungus into culture from them. The oospores though present in plenty did not germinate when plated. Attempts were then made to bring the fungus into culture by introducing aseptically removed bits of the stem into oatjuice agar tubes. The fungus grew in all the tubes producing sporangia, but the cultures were badly contaminated by bacteria. Sporangia from portions of the tubes least contaminated by bacteria were removed and plated. The germinated sporangia were transferred to oatjuice and Frenchbean agar tubes. Though some of the tubes were contaminated, in a few the fungus mycelium soon outgrew the bacterial colonies; bits of agar with mycelial growth farthest from the bacterial colonies were transferred into oat agar again. Cultures from this series were mostly pure. From these pure cultures several subcultures were made. The fungus isolated in 1921 unfortunately died out. In 1923 it was again brought into culture from fresh material obtained from the botanical gardens at Ootacamund and once again in 1924 and these were used for further work.

After the fungus was brought into pure culture a number of inoculations were carried out on antirrhinums and several other plants that were known to be hosts of Phytophthora, in pots kept inside glass cages whose bases were strewn with moist sand. Before inoculation the plants were sprayed with distilled water. Bits of agar cultures of the fungus were placed on the leaves or stem as the case may be, and on the top of these moist cotton wool was kept. In some cases plasticine was made up into cups round the base of the stem and bits of agar cultures with sterile water were kept in these and the cups covered with moist cotton wool. Arecanut leaf bud was inoculated by placing bits of agar cultures between the folds of the leaves and enclosing the entire bud in a chimney whose ends were plugged with moist cotton wool. Potato tubers and tomato fruits were first washed with mercuric chloride solution (1-1000 strength), then with sterile water and placed inside sterilised moist chambers and inoculated with bits of agar cultures. In some cases suspensions of sporangia were used.

Inoculations with Phytophthora pini var. *antirrhini.*

Name of plant	Previously known to serve as host for	Nature of inoculation	Number inoculated	Number infected	Remarks
Antirrhinum seedlings	....	Bits of culture placed at collar.	3	3	Plants wilted in a week.
Ditto	....	Control . . .	2	..	Remained healthy.
Antirrhinum older plants	....	Bits of culture placed at collar region.	4	4	
Ditto .	....	Control . . .	2	..	Remained healthy.
Ditto .	....	Planted in an old pot where previous inoculations were made.	1	1	
Ditto .	....	Control in pot with sterilised soil.	1	..	Remained healthy.
Ditto .	....	Surface soil mixed with culture of the fungus.	1	1	
Ditto .	....	Control with sterilised soil.	1	..	Healthy.
Ditto .	....	Surface soil replaced with soil from an infected pot.	2	2	The plants were grown in pots with sterilised soil. The surface soil was removed and was replaced with soil from a pot in which previous inoculations with the fungus were made.
Ditto	....	Surface soil replaced with sterile soil.	2	..	Healthy.
Antirrhinum old plants	....	Bits of culture placed at the collar.	6	5	One was not affected, while the others wilted.
Ditto .	....	Control . . .	1	..	Healthy.
Ditto .	....	Bits of culture on leaves.	3	*Nil*	No infection.
Ditto .	....	Control . . .	3	..	Healthy.
Ditto .	....	Bits of culture on flower buds.	4	3	3 buds were rotten.
Ditto .	....	Control . .	3	..	Healthy.
Ditto .	....	Bits of culture on terminal shoot.	4	*Nil*	
Ditto	....	Control . . .	3	..	Healthy.
Jasminum .	Ph. Syringae known on Jasminum nudiflorum.	Bits of culture on young buds.	4	*Nil*	The buds were introduced into potato tubes in which a small quantity of water was kept, and plugged with moist cotton wool.
Ditto . . .	....	Control . . .	2	..	
Ditto . . .	....	Bits of culture on mature leaves.	6	*Nil.*	
Ditto .	....	Control . . .	2	..	

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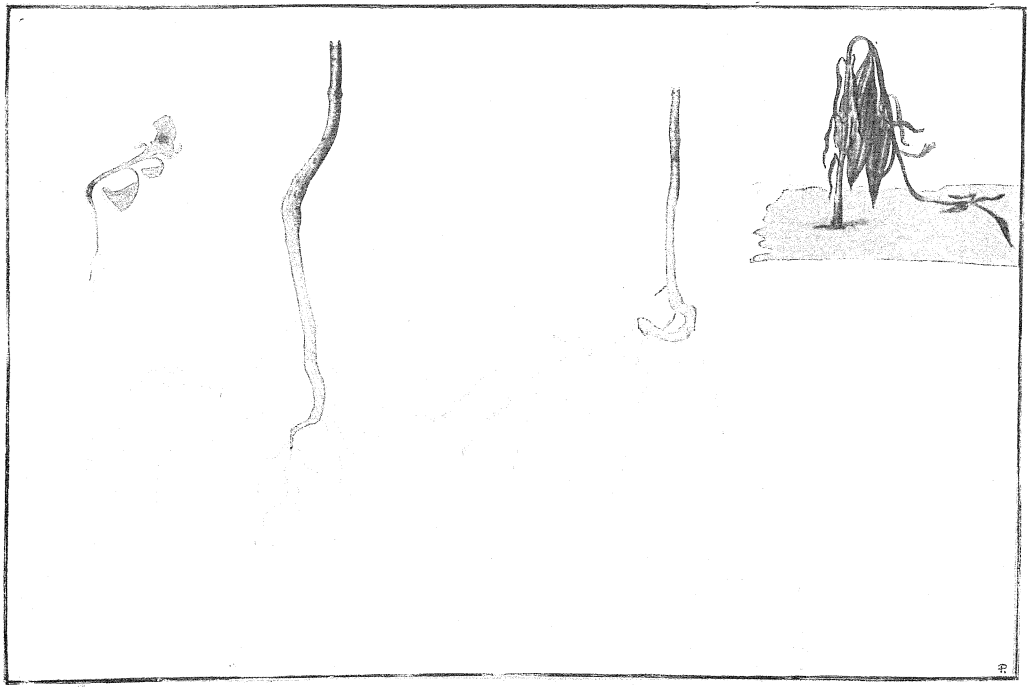


Seedlings infected with the fungus.

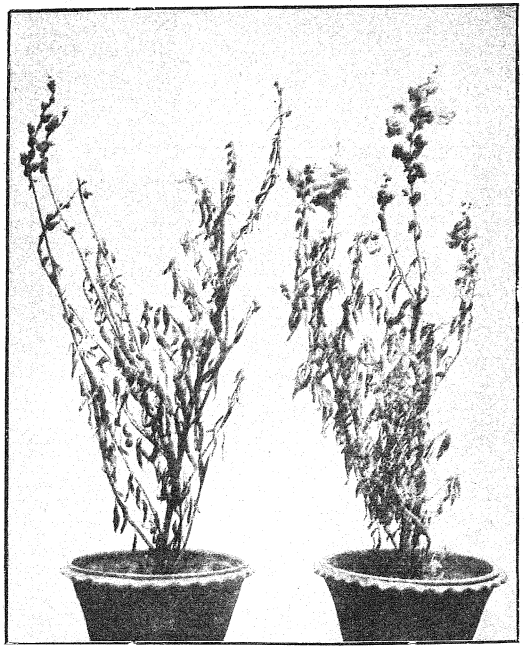
Inoculations with Phytophthora pini var. *antirrhini*—contd.

Name of plant	Previously known to serve as host for	Nature of inoculation	Number inoculated	Number infected	Remarks
Vinca. mature plant	Ph. parasitica .	Mature leaves .	3	*Nil*	
Ditto .	....	Control . . .	3	..	
Ditto .	....	Stem . . .	3	..	
Ditto .	....	Control . . .	2	..	
Vinca. mature plant in a pot.	Ph. parasitica .	Bits of culture on fruits.	4	..	
Ditto .	....	Control . . .	4	..	
Opuntia dillenii a potted plant.	Ph. cactorum and Ph. Syringae on several cacti.	Base of plant unwounded.	4	..	
Ditto .	....	Control . . .	2	..	
Ditto .	....	Buds . . .	4	..	
Ditto .	....	Base of plant wounded.	4	..	
Ditto .	....	Control . . .	2	..	
Colocasia antiquorum potted plants.	Ph. Colocasiae .	Leaves . . .	4	..	
		Control . .	2		
Ricinus communis seedlings in pots.	Ph. parasitica .	Leaves . . .	4	..	
Ditto .	....	Cotyledons . .	4	..	
Ditto .	....	Stem round the base	3	..	Plasticine cups were placed round the base of the stem and bits of culture were placed in them with water.
Ditto .	....	Control . . .	2 plants.	..	
Tomato seedlings in pots.	Ph. Omnivora, arecae, infestans, parasitica, and Faberi.	Base of stem . .	4	..	
Ditto .	....	Terminal buds .	4	..	
Ditto .	....	Control . .	2 plants.	..	
Tomato fruits . .	Ph. cryptogea, terrestris and infestans.	Bits of culture and suspensions of sporangia (unwounded).	2	..	The fruits were washed in 1-1000 mercuric chloride solution and then in sterile water and kept inside moist chamber.
Ditto .	....	Bits of culture and suspensions of sporangia (wounded).	2	..	
Ditto .	....	Control . . .	2	..	
Sunflower seedlings .	....	Base of stem . .	2	..	
Ditto .	....	Control . . .	2	..	
Potato plant in pots	Ph. infestans, parasitica.	Base of stem . .	3	..	
Ditto .	....	Leaves . . .	5	..	
Ditto .	....	Young buds . .	4	..	
Ditto .	....	Control . . .	2	..	

Inoculations with Phytophthora pini var. *antirrhini*—concld.

Name of plant	Previously known to serve as host for	Nature of inoculation	Number inoculated	Number infected	Remarks
Potato tubers	Ph. infestans, cryptogea, erythroseptica.	On tubers (unwounded).	2	..	Tubers washed in 1-1000 mercuric chloride solution and then in sterile water and kept inside moist chamber.
Ditto	....	On tubers (wounded)	2	..	
Ditto	....	Control	2	..	
Bread-fruit	Ph. omnivora	Bits of culture on fruits.	2	..	In these cases the fruits were first washed in 1-1000 mercuric chloride solution and then in sterile water and placed in sterile moist chambers.
Ditto	....	Control	1	..	
Cocoa fruits	Ph. Faberi, Theobromae.	Fruits	3	..	
		Control	2	..	
Papaya fruits	Ph. Faberi	Bits of culture on fruits.	4	..	
		Control	2	..	
Panax, potted plant	Ph. cactorum	Bits of culture placed on leaves.	8	3	3 of the leaves showed rotting but Phytophthora was not visible on them.
Ditto	....	Suspensions of sporangia on leaves.	6	..	
Ditto	....	Bits of culture	5	..	
Ditto	....	Control	4	..	
Chillies	Ph. capsici	Bits of culture on leaves.	6	..	
Ditto	....	Base of the stem	3	..	
Ditto	....	Control	2	..	
Tobacco seedlings	Ph. nicotiana	Culture on leaves (unwounded).	6	..	
Ditto	....	Culture on leaves (wounded).	4	..	
Ditto	....	Control	4	..	
Arecanut leaf bud	Ph. arecae	Bits of culture between the folds of the leaves (unwounded).	6	..	
Ditto	....	Bits of culture between the folds of the leaves (wounded).	6	..	One small spot was seen round one of the wounds, but there was no further development.
Ditto	....	Control	4	..	
Brinjal, potted plant	Ph. omnivora, Melongena.	Culture on leaf	3	..	
Ditto	....	Collar region (unwounded)	3	..	
Ditto	....	Collar region (wounded).	3	..	
Ditto	....	Control	3	..	
Petunia seedlings	Ph. parasitica	Base of stem and young buds.	8	..	
		Control	4	..	

PLATE III.



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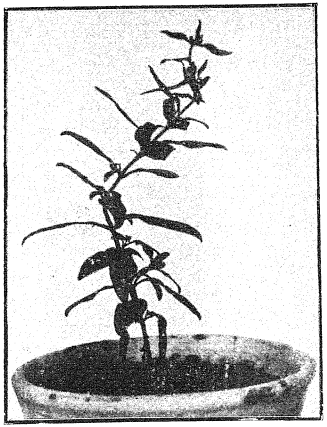

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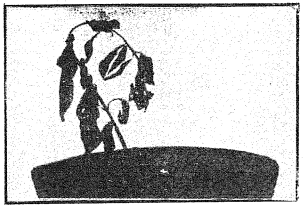

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1. Photograph of diseased plants. 2. A healthy seedling (control). 3. Inoculated seedling.

The results of these inoculations show that the parasitism of the fungus is practically limited to antirrhinum and on this the same symptoms are reproduced as are seen in nature. The collar region in young infected plants gets a watersoaked appearance and the leaves begin to droop ; the rotting of the collar region becomes evident and the plant dies. Microscopic examination of the infected portions shows the presence of the fungus in the tissues of the wood and pith. In some cases a few sporangia were seen on the rotten bark. Eelworms invade the badly rotten portions. The fungus appears to make its entrance through the stomata on the stem in the young plants as is seen from sections of the inoculated portions. Infection is mainly through the soil and the disease spreads through infected soil. The leaves and the crown of the plants are not affected by the fungus but the flowers can be infected. Natural infection of flowers is not noticed. The fungus loses its virility if grown on artificial media for a long time. Cultures 20 months old were not able to infect antirrhinum plants effectively.

Growth on culture media.

The fungus was cultivated on a variety of agar media and its growth on them was observed.

Glucose agar. The growth is mainly submerged and the surface of the agar presents a granular appearance. The submerged hyphae are very much budded and no oospores or sporangia are produced.

Potato agar. The growth of the fungus is slow, and the surface of the agar has a powdery granular appearance. Even after two weeks no spore formation is observed. The submerged hyphae have a budded appearance.

Oat juice agar. A white fluffy luxuriant growth occurs with the production of numerous oospores. In some tubes sporangia are produced in the beginning but only oospores later.

French bean agar. This is by far the best of the media used for the cultivation of the fungus. There is a white fluffy luxuriant growth. In all cultures oospores are produced in large numbers. No sporangia are observed in cultures except in rare cases.

Wheat agar. The growth on this medium is not as good as on oatjuice agar. At first there is a submerged growth but later on aerial growth is also observed. Oospores are formed in numbers.

Cholam meal agar. There is a poor growth of the fungus with scanty and sparse aerial growth. Oospores are formed.

Bengal gram agar. A good white fluffy growth is formed with numerous oospores.

Cornmeal agar. The growth is the same as on wheat agar with formation of oospores.

Cotton seed agar. There is a white fluffy aerial growth but not as good as on French bean or oatjuice agar, with a number of oospores.

French bean agar with ant decoction added to it. A good white cottony aerial growth occurs with the formation of a number of oospores.

Sterilised French bean seeds. A luxuriant white growth of fluffy mycelium enveloping the seeds is formed. No sporangia are seen but very few oospores are observed.

Sterilised carrots. Good aerial growth is visible and a number of oospores are formed in the tissues of the medium.

Sterilised potato slants. There is a good white fluffy growth but no sporangia nor oospores are observed.

Sterilised slants of Amorphophallus corm. A good white growth of the fungus is formed and oospores are produced.

The effect of reaction of media. French bean agar medium of varying Fuller's scale was used. Two tubes of each kind were inoculated with the fungus from the same culture and on the same day.

No.	Reaction	Growth after 15 days	Kinds of spores formed	Remarks
1	−10	Very poor growth mostly submerged and not aerial.	No spores . . .	The medium was dark.
2	−5	Very poor submerged growth.	Ditto . . .	Ditto.
3	Neutral	Good white aerial growth	Sporangia and oospores	Ditto.
4	+5	Very good aerial growth	Oospores and not many sporangia.	The medium was of the usual colour.
5	+10	Ditto . .	Ditto . .	Ditto.
6	+15	Ditto . .	Oospores and sporangia	The medium did not set well.
7	+20	Good white and fluffy growth.	Sporangia and few oospores	Ditto.
8	+25	No growth . . .	....	The medium was in a liquid state.
9	+30	Ditto . . .	....	Ditto.
10	+35	Ditto . . .	....	Ditto.

Malic acid and NaOH solutions were added to the media to make them acidic or alkaline as the case may be. Sporangia were produced in all the tubes from neutral to +20. In alkaline media the growth of the fungus was very poor. Evidently, the fungus thrives well on an acidic medium of the reaction +5 to +15.

Hot weather seems to have an adverse effect on the growth of the fungus in culture. The present culture of the fungus was obtained in July 1924. In April 1925 sub-cultivation of the fungus in fresh French bean agar tubes failed to produce any growth. Several sub-cultivations were tried but without success. The cultures were not dry and there were a number of oospores. It was thought that the cultures would be of no use for further work. As a last resort the tubes were cooled to know whether it could have any effect in rejuvenating the fungus. Four tubes were kept in a beaker of water into which powdered ice and salt were added. This brought down the temperature of the water very low. Ice was added only for one day. From the next day onwards the tubes were kept in a beaker containing cold water which was changed twice a day for two weeks. A slight growth appeared in one of the tubes which was at once sub-cultivated on French bean and oatjuice agar tubes. The sub-cultured tubes were kept in water and the growth was very slow at first. But from the second series of sub-cultivations the fungus grew well and the tubes were kept out of water. Sub-cultivations of these on wheat agar and cotton seed agar were kept both in water and outside it to note if there was any appreciable difference in the growth of this fungus due to this treatment. A more vigorous and fluffy growth was observed in the tubes kept in water than in those kept outside. On oatjuice agar tubes similarly treated, there was not any appreciable difference in growth.

The growth of the fungus in cultures kept in darkness, in diffused light and in direct sunlight was tested. Two tubes each of freshly inoculated cornmeal agar were kept in darkness (inside a dark chamber), in diffused light (inside the laboratory opposite a glass window) and in direct sunlight on the roof. Two sets of tubes were kept exposed to direct sunlight. One set was placed in an empty glass beaker and another in a beaker containing water. The water was changed twice during the course of the experiments. The tubes were examined after 10 days. There was good growth of the fungus in the tubes kept in darkness and in diffused light there being no difference in growth between the two while in the two sets of tubes exposed to direct sunlight there was no growth of the fungus at all. The temperature of the tubes kept in open sunlight rose up to 42·5°C in the empty beaker and 40°C in the one with water and this must account for the failure of the fungus to grow.

The Morphology of the Fungus. The mycelium of the fungus in culture is, as is characteristic of the genus, coenocytic in the early stages and measures normally 5-10μ in thickness. In the old hyphae whose cell contents have disappeared septa are present. The aerial hyphae remain even and unbranched for long distances. The submerged mycelium is of varying thickness and much branched, the branches being short and irregularly swollen. A number of knob-like protuberances are often seen on the submerged hyphae producing a much budded appearance. On the sides of the tubes and at the top of the agar slant the mycelium branches dichotomously with a fanlike appearance.

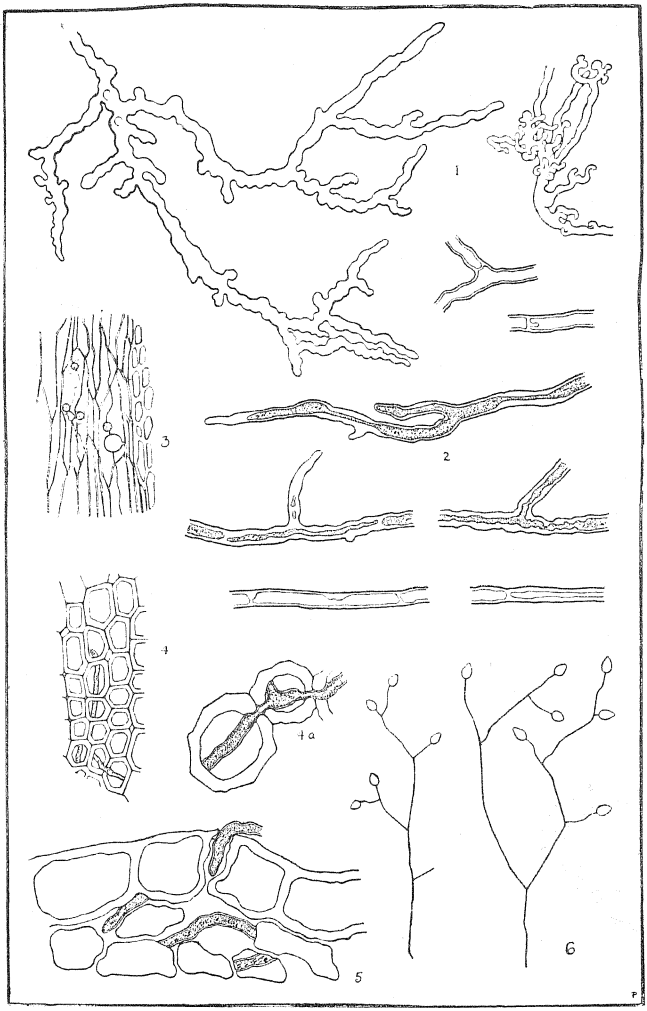
The contents disappear in old hyphae which look like tubes. Septa are present in them. These are mainly seen far apart but sometimes occur frequently. The septa may be thick or thin. They are of even thickness or one half may be very thick and the other half thin. They may have a small projection in the centre. Sometimes they are capshaped and protrude on one side with a corresponding depression on the other. Generally they are concavo-convex.

Thickenings are often observed in the hyphal wall. These are cellulose deposits and extend for a short length or continue for some distance. They appear on one side alone as small elevated cushions or on both sides leaving a narrow space in the centre; or the two coalesce filling up the entire space and forming a partition. In some cases the thickenings extend for a long distance on one side of the hypha or they are formed on both sides leaving a narrow hairlike pore in the middle. They may coalesce in several places leaving discontinuous spaces. In some cases the entire hypha is filled up having an appearance of a cellulose rod. These thickenings are not dissolved when treated with KOH solution which shows that they are not composed of callose.[1]

Sporangia. Sporangia were observed but rarely in cultures and on the affected plants. In the cultures that were first obtained from the diseased material a number of sporangia were produced. These appeared for 3 or 4 sub-cultivations gradually diminishing in number and practically disappearing later on. But occasionally one French bean tube or other showed the presence of a few of them. In French bean cultures of different Fuller's scale sporangia were produced in large numbers in some of the acidified media and in the neutral. Except in some of the French bean and oatjuice tubes no sporangia were formed in any of the cultures.

Since the sporangia were rare on solid media, other methods of inducing sporangial formation were tried. As they are known to be easily produced in water, bits of the culture on French bean agar were placed in sterilised water kept in watch glasses inside moist chambers. In two days numerous sporangia were formed. Sporangial formation was tried in tap water, rain water, old distilled water, fresh distilled water and fresh sterilised water. More or less the same quantity of culture was put in each kind kept in sterilised watch glasses, inside sterilised petri dishes which were kept in moist chambers. In the first 3 kinds of water numerous sporangia were seen within 36 hours while in the last two the sporangial formation was a bit delayed. Though at first more sporangia were seen in the 3 former no difference could be made out among the dishes after 3 more days. During one of the experiments (it was in March 1925) no sporangia were formed in bits of culture placed in tap water while they were produced in distilled water. It was suspected that this might be due to certain salts held in solution in the tap water and a series of experiments were conducted to test the sporangial formation in solutions of certain salts. The dishes were examined 3 days after placing the bits in them.

[1] Dastur, J. F. On Phytophthora parasitica. A new disease of the castor, oil plant. *Memoirs of the Department of Agriculture in India*, Vol. V, pp. 177-231.



1. Submerged hyphae. 2. Septa and thickenings in the hyphae. 3. Tangential section of the stem showing oospores being formed inside the tissues. 4. Cross section of the wood showing intracellular hyphæ (× 264). 4a. Same enlarged (× 528). 5. Penetration of hypha into the stem of a seedling (× 528). 6. Sporangiophores and sporangia in water (diagrammatic).

No..	Strength of solution	Calcium chloride	Magnesium chloride	Sodium chloride
	Per cent.			
1	0·25	Very numerous . .	Very numerous . .	Very numerous.
2	0·5	Numerous . . .	Numerous . . .	Very numerous.
3	0·75	Less than in 2 . .	Less than in 2 . .	Same as others. (Less than in 2.)
4	1·0	Few	Few	Few.
5	1·25	....	....	Few.
6	2·0	....	....	....

The results show that the formation of sporangia decreases as the concentration of the solutions increases. Bits were kept in distilled water along with these and it was observed that a larger number of sporangia was produced in it and that much earlier. Though only very few sporangia were seen in 1 and 1·25 per cent. solutions of sodium chloride after 3 days, more sporangia were produced later on. In experiments made in March 1925 just before the fungus died out in culture no sporangial formations were seen when cultures were placed in 0·125 per cent. solution of sodium chloride.

Leonian [1] mentions that sugars produce abundant asexual reproduction in Phytophthora. In order to test the formation of sporangia of this fungus in sugar solutions bits of culture were placed in 1 and $\frac{1}{2}$ per cent. solutions of three sugars. Along with these, bits were placed in distilled water also for comparison. The dishes were examined after 5 days.

Strength	Glucose	Lactose	Maltose	Distilled water
1 per cent	*Nil*	Numerous more than in distilled water.	*Nil*	Numerous.
$\frac{1}{2}$ „	Do.	Ditto .	One	——

From the foregoing it is seen that the sporangia are formed only in lactose and not in the other two sugars with the above concentration.

Sporangia are produced terminally on sporangiophores which in some cases can be distinguished from ordinary hyphae only by the presence of sporangia and by their fineness. The growth of the sporangiophore is continued sympodially by a branch being produced below the terminal sporangium. The sporangiophores are generally of uniform thickness but sometimes they are inflated at various points. The sporangium itself may be set on the top of a small swelling. There may be two or three swellings at intervals along the length of the sporangiophore. From a swelling one or more lateral branches may be given off. These may remain blunt or may bear sporangia.

[1] Leon H. Leonian. On the physiology of the Genus Phytophthora. Abstract in Phyopathology, Vol. 14, p. 32.

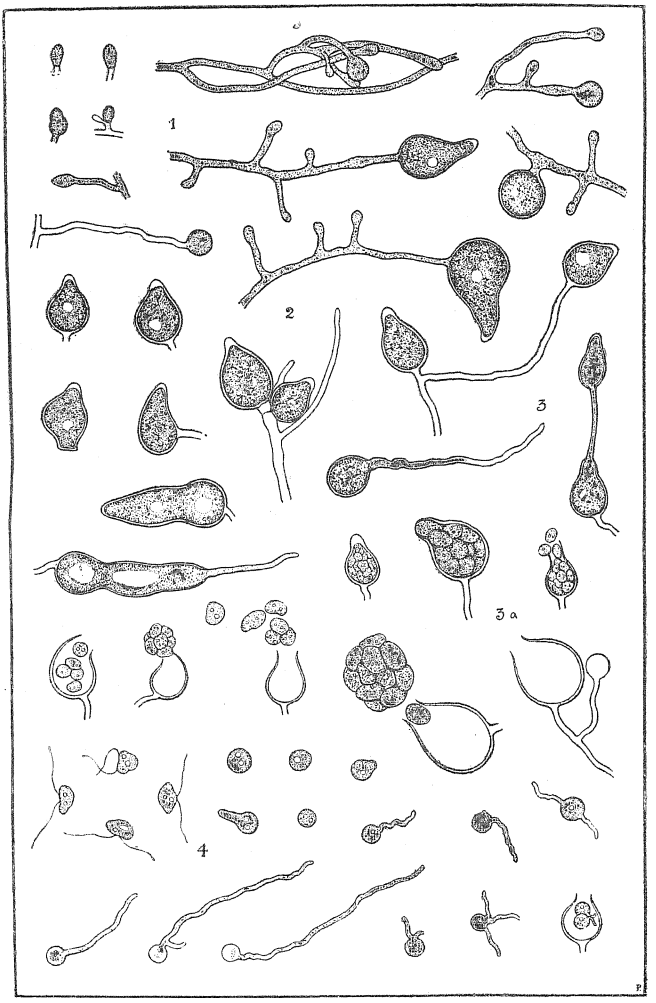
Sporangia are normally ovate or pearshaped with a distinct papilla. Occasionally globular sporangia are also found. In abnormal cases, for example, when the culture has been long in water, some sporangia become very much elongated. Usually, there is only one papilla but rare instances with two papillae have been noticed. The papillary end is clearer than the rest of the sporangium. The attachment to the sporangiophore is at the broader end opposite the papilla but in some it is on a side. The sporangial wall is hyaline and the contents are finely granular. Often a distinct vacuole is present in the centre of the sporangium. Sporangia vary in size; those formed in agar cultures are generally big and measure $51{\cdot}8\times39{\cdot}8\mu$ (the limits being $39{\cdot}3$—$66{\cdot}8\times32{\cdot}1$—$42{\cdot}8\mu$) while those formed in water are smaller measuring $30{\cdot}3\times20{\cdot}2\mu$ (the limits being $18\text{-}60\times12\text{-}36$). Of the latter those that are formed first are bigger but the ones produced later are smaller in size.

The sporangium originates as a small terminal swelling. At first some of the sporangia are globular and only assume the ovate shape as they mature. Some are ovate from the beginning with a central vacuole, and as they grow, only increase in size. No intercalary sporangium has been noticed.

Sporangia are produced in light and in darkness; only, they are formed much earlier in light. One series of bits of culture placed in water in petri dishes were kept in the verandah and another inside a dark chamber. Two days later the series placed in the verandah had produced numerous sporangia while the one kept in darkness had not produced any. But two days later still the latter also had formed numerous sporangia.

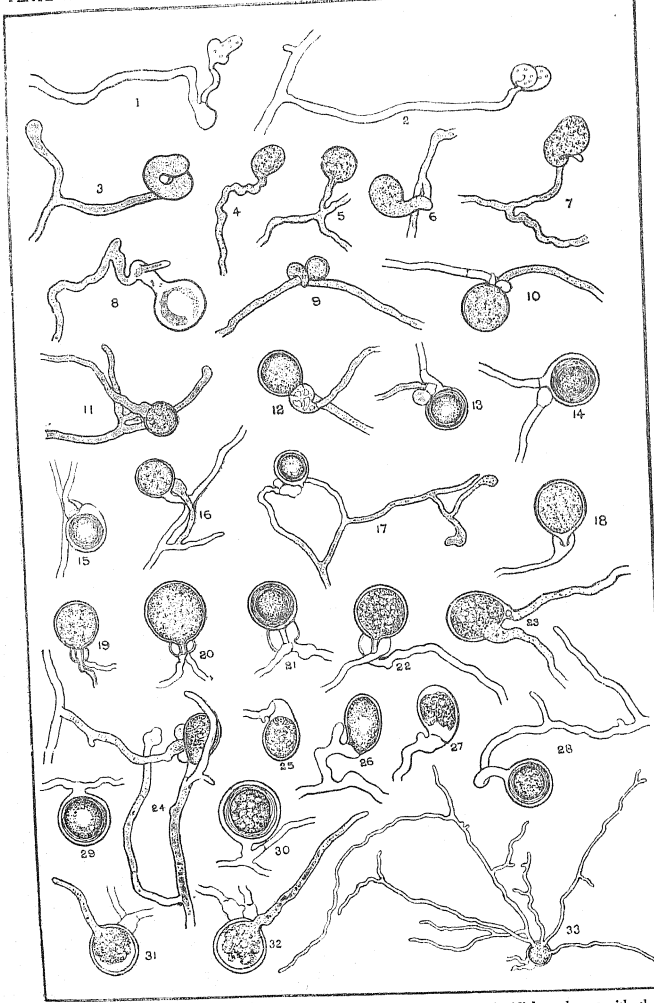
The sporangium germinates either conidially by the production of a germ tube or by the liberation of zoospores. In culture media germination is mostly conidially. Sporangia which have been in water for a long time also germinate conidially. The germ tubes are usually produced at the papillary end. They may be formed as a direct continuation of the papilla or from a side of the papilla or just below it from a side of the beak. In some of the platings, germ tubes had been produced from all sides of the sporangium. The germ tube is at first simple and branches afterwards or may be branched from the very place of origin. Sometimes a secondary sporangium is formed at the tip of the germ tube and this again germinates forming another. Thus three sporangia have been observed in a chain the lower ones being empty while the topmost one is full of protoplasm.

Germination by Zoospores. Many of the sporangia liberate zoospores. In 7-15 minutes after a transfer is made to a drop of water kept on a slide a number of sporangia produce zoospores many of which can be seen moving about in the water. Zoospore formation is observed at first while later on conidial germination takes place. In some cases the zoospores come out one by one. The protoplasm inside the sporangium gets rounded into distinct bodies; the papillary end becomes clear; there is a rotatory movement inside the sporangium; the papillary end dissolves and the zoospores swim out one by one. Sometimes all the zoospores do not come out. One or two remain inside the sporangium and though they execute all sorts of movements they do not come out.



1. Sporangial incepts and the swellings on the stalks. 2. Sporangia. 3. Conidial germination. 3a. Sporangial germination. 4. Zoospores and their germination.

PLATE VI.



1, 2 & 3. Antheridia. 4-8. Oogonial incepts. 9-24. Different forms of antheridial attachment with the formation of oospores. 25-27. Abortive oogonia. 28-30. Oospore-like bodies but with no evidence of antheridia (probably parthenogenetic). 31-33. Germination of immature oospores.

In other cases the protoplasmic contents of the sporangia get rounded; vague outlines of the potential zoospores become visible; there is a streaming movement of the protoplasm; the papillary end dilates as it were and the entire protoplasmic contents stream out and collect outside the mouth. A few moments later one by one the zoospores swim out from the congregation. No vesicle formation was found.

Zoospores. Zoospores swim about in the water actively as soon as discharged. They are thick in the middle and tapering towards the ends. One side is slightly concave. Two cilia are produced from this side. Each zoospore has 2 vacuoles of unequal size. The number of zoospores produced by each sporangium varies from 2-16 according to the size of the sporangium. After moving about for some time they come to rest, shed their cilia and round themselves off. At this stage the protoplasm is found to accumulate on a side or round the periphery with the formation of a big vacuole. When they have come to rest the zoospores measure 9-12μ in diameter. In less than half an hour the zoospores begin to germinate by the production of germ tubes given off from one or more sides. These are either simple or branched. In some cases the entire contents of the zoospores pass out into the germ tube and the original zoospore looks like an empty vesicle. Some of the zoospores which do not come out of the sporangium germinate *in situ*. Light does not exert any influence on the germination of zoospores. Those kept in darkness and in light germinate equally well.

Sexual organs. Sexual organs are produced in the majority of the cultures and even in cultures where no sporangia are observed oospores are numerous.

The antheridium and oogonium originate as branches of different or at times of the same hyphae. They begin to appear in cultures 3 or 4 days after the inoculation. The antheridial branch is either short or a little elongated with the end bulged out into a small irregular swelling of various shapes. The antheridium may be simple or branched. The branches may originate from the antheridial hyphae or the swollen end. At times the swollen end is elongated and twisted. In the initial stages antheridia are full of finely granular protoplasm.

The oogonium originates as a globular or pearshaped swelling at the tip of a branch. The oogonial stalk may be short, or long and twisted. The oogonia are at first hyaline and full of granular protoplasm and are bigger than the antheridia. The oogonia and antheridia are cut off from the hyphae by septa.

Fertilisation is effected by the union of the antheridium and the oogonium. Different kinds of attachment of the antheridia to the oogonia have been observed. (1) The antheridium attaches to the oogonium by coiling round the base of the oogonial stalk just at the junction of the oogonium with the stalk thus encircling it. (2) The antheridium is attached to the base of the oogonium and the oogonial stalk is observed to pass through the antheridium as though the oogonium has grown through it. (3) The antheridium attaches itself to the base of the oogonium either superimposed on the stalk or just by the side of it. (4) The antheridial attachment is on a side of the oogonium removed from the point of insertion of the stalk. No fertilisation tube has been observed. How exactly the passage of the contents of

the antheridium takes place is not known. In later stages the antheridia are empty and remain attached to the oogonium.

After fertilisation the oospore wall begins to be differentiated and gradually gets thickened with a change in colour. When fully mature the wall measures 3-3·75μ in thickness. It is found to be composed of fine concentric layers. The contents of the oospore are at first finely granular and distributed evenly throughout but later there is a differentiation into a peripheral dense portion and a central clearer area. This area has sometimes an irregular outline. In some, 2 or 3 oil globules fill up the oospore.

The oospores are round and smooth and are always found lying inside the persistent oogonia which they do not completely fill. The colour of the oospores varies in different cultures and sometimes in the same culture. In oatjuice agar and carrot the oospores are of a light yellow colour. From this there is every gradation to dark reddish brown (amber) in some French bean agar cultures. They measure 26·2μ on an average (the extremes being 18 and 30·6μ). The persistent oogonia are spherical or nearly so, the average diameter being 30·87μ (varying between 21·6 and 36μ). 200 each of the oospores and oogonia were measured and the diameter and frequencies are represented graphically below.

GRAPH I.

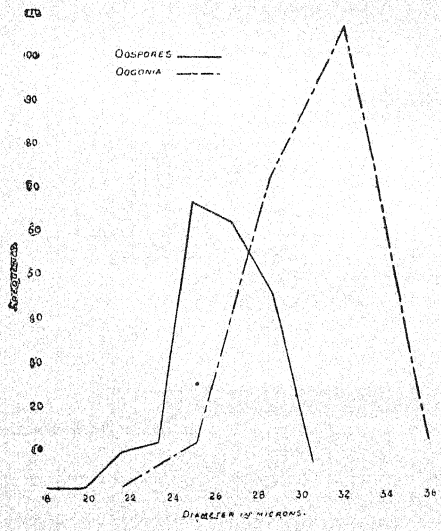
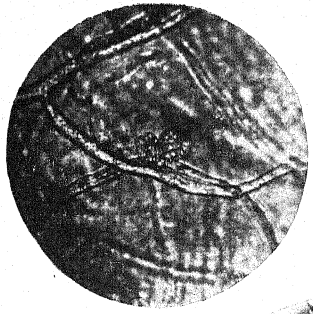
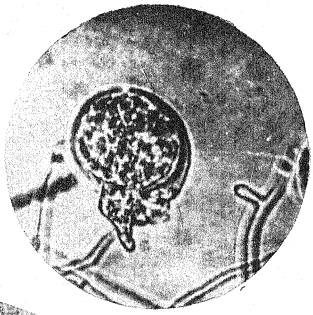


PLATE VII.



1



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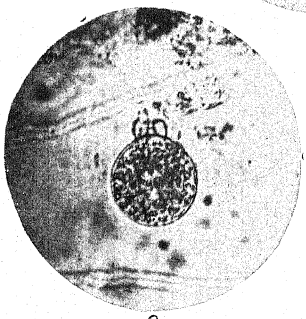

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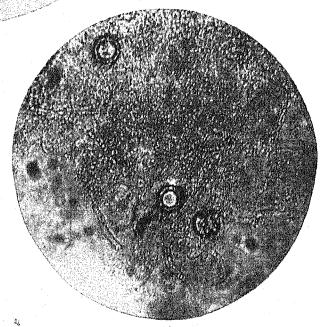
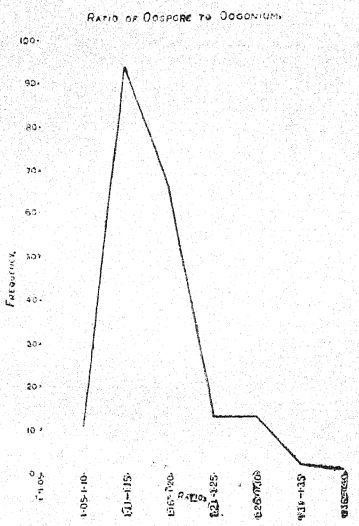


4

Microphotographs of :—1. An antheridium coiling round an oogonium. 2. Oospore formation. 3. Amphigynous antheridium. 4. Mature oospores. 5. Germination of an immature oospore—the antheridium was crushed and the contents came out while taking the photograph.

The ratio between the oospores and oogonia was calculated. It was found that the greatest number have a ratio between 1·11 and 1·15. The graph below represents the ratios.

GRAPH II.



Rarely, oospore like bodies were formed which differed from oospores in the absence of any trace of the antheridium on the oogonia, inside which they were formed. They were of about the same size as the oospores. Either the antheridia might have been separated completely while removing or they might have been parthenogenetically developed. Chlamydospores have not been noticed in cultures of this fungus.

Germination of oospores. Attempts to germinate the mature oospores were not successful. Oospores from old cultures were kept in water and in moist sand for 20 days and yet no germination was noticed. But when young and immature oospores were kept in water they germinated in the course of 1 or 2 days with the production of germ tubes. Oogonia with antheridia attached (probably fertilised) were also found to germinate with the formation of a germ tube.

The fungus perennates in the soil. Bits of infected roots or pieces of the bark with the oospores may be left in the soil after the removal of the plant and these form sources of further infection. Plants grown in pots which contained infected soil were attacked while those in sterilised soil were healthy. Addition of infected soil to the base of plants grown in sterilised pots produced the disease. This clearly shows that the disease is spread through the soil. Experiments are in progress to find out a practical method of combating the disease, and the results will form the subject of a further publication.

Affinities of the fungus. *Phytophthora cryptogea* has been recorded on antirrhinums. The fungus isolated locally from diseased antirrhinums differs from the former, because the latter forms both paragynous and amphigynous antheridia, while *P. cryptogea* has been known to form only amphigynous antheridia. Again *Ph. cryptogea* infects tomato plants and fruits, while the other does not.

Lafferty and Pethybridge [1] classify the different species of Phytophthora into 4 main groups based on the mode of development of their sexual organs.

1. Species in which so far as is known at present the antheridia when present are always amphigynous.
2. Species in which the antheridia are preponderatingly paragynous but are sometimes amphigynous.
3. Species in which so far as is known at present the antheridia are always paragynous.
4. Species in which the mode of development of these organs is not known or in which these organs have not yet been found.

According to this classification the antirrhinum fungus falls into the 2nd group which includes *Ph. cactorum*, *P. syringae*, *P. fagi* and *P. pini*.

Phytophthora cactorum [2] produces numerous sporangia with prominent papillae measuring 34·5 ×27μ. Spheroconidia—round usually intercalary spores 33-40 μ in diameter—germinating by germ tubes occur. Oospores are formed in plenty and measure 27μ. The fungus is parasitic on Panax and several cacti. *Phytophthora fagi* [3] also produces abundant sporangia measuring 40-74×30-32μ. Simple and branched haustoria are present. The oogonia are intercalary and are seen in water and agar cultures. Oospores measure 30·2μ. Sphero-conidia are formed. The fungus infects Fagus sp. and several cacti.

Phytophthora syringae [4] produces sporangia rather sparingly. The free end of the sporangium is blunt and the papillae are broad and flat. Sporangia measure

[1] Lafferty, H. A., and Pettybridge, G. H. On Phytophthora parasitic on Apples which has both amphigynous and paragynous antheridia and on allied species which show the same phenomenon. Scientific proceedings of the Royal Dublin Society, Vol. XVII, N. S. 4, pp. 29-43-1922. Abstract, *Review of Applied Mycology*, Vol. II, pp. 181-183.

[2] Rosenbaum, J. Phytophthora disease of Ginseng. *Bulletin 363. Cornell University Agricultural Experiment station of the New York State College of Agriculture.*

[3] Guy W. Wilson. Studies in North American Peronosporales. V. Review of the Genus Phytophthora. *Mycologia*, Vol. VI, pp. 54-83,

[4] *Loc. cit.*

40×27μ. On germination a vesicle is formed. The oospore which partially or completely fills the oogonium is generally hyaline. The average diameter of the oogonia and oospores are 27·3 and 25μ respectively. The fungus is parasitic on Syringa vulgaris, cacti and several species of jasminum.

In *Phytophthora pini* [1] the sporangia are large, terminal or rarely intercalary. The papillae are well-defined or blunt sometimes lacking altogether. Sporangia measure 55·5×35μ (the extremes being 26-92·5×22-44·5μ). Oogonia are formed on solid agars and also abundantly in nutrient solutions, and have a mean diameter of 29μ (18·5-37). Antheridia are bothp aragynous and amphigynous with usually only one antheridium to each oogonium but 2, 3 and even 4 may be attached to the same oogonium. Both types of antheridia on the same oogonium are not uncommon. This is a weak parasite on the roots of Pinus resinosa.

Antirrhinum Phytophthora differs from *P. cactorum* and *P. fagi* in the rare and limited production of the sporangia and in the absence of sphero-conidia. The oospores measure 26·2 μ and are smaller than those in either of the two latter species. It does not infect either Panax or cactus, its parasitism being confined to antirrhinums alone.

It resembles *P. syringae* in the sparing formation of sporangia but differs from it in the presence of a more prominent papilla and in the absence of vesicle formation. The oogonia and oospores are bigger and the ratio between the sizes of the oospores and oogonia is more pronounced than in *P. syringae*. The oospores are not hyaline as in *P. syringae* but light yellow to amber in colour depending on the medium. It does not infect jasmine which is parasitized by *P. syringae*.

Antirrhinum Phytophthora has many characters in common with *P. pini* but does not entirely agree with it. In the latter the sporangia are said to be rarely intercalary but are never so in the former. The size of the sporangium is bigger on an average in *P. pini*. The mean size of the oogonium is different in the two fungi, that of *P. pini* being 29μ and of the other 30·87μ. The size of the oospores of *P. pini* is not given and so no comparison could be made of the size of the oospore. In *P. pini* more than one antheridium has been found attached to one oogonium and the presence of both types of antheridia on the same oogonium is not uncommon. Such phenomena were not observed in the antirrhinum fungus. Prof. Ashby to whom a culture of *Antirrhinum phytophthora* was sent for comparison writes that "perhaps it is a strain" of *P. pini*; but the authors have found them to differ in certain respects. Hence *Antirrhinum Phytophthora* may be considered to be a variety of *P. pini*. Since its parasitism is restricted to antirrhinums, it is proposed to name it as *Phytophthora pini* var. *antirrhini*.

Phytophthora pini var. *antirrhini*, n. v. Sporangia produced but rarely in agar cultures and abundantly in water, terminal, never intercalary, ovate or pear shaped, sometimes globose, papillate with a prominent papilla, 41×30μ on an average

[1] Leonian, L. H. Physiological studies of the Genus Phytophthora. *American Journal of Botany*, Vol. XII, pp. 444-498.

(varying from 18·66·8×12·42·8). Oospore produced in plenty on solid agar media, 26·2μ mean diameter, spherical with a thick wall and lying inside a persistent oogonium which it does not completely fill, yellowish to reddish brown in colour; Oogonia 30·87μ mean diameter; Antheridia both paragynous and amphigynous, more commonly paragynous, on solid media.

A parasite on *Antirrhinum majus* on the Nilgiris.

We are indebted to the Curator and staff of the Botanic Gardens, Ootacamund, for their help in carrying out the investigation. Our thanks are due to Prof. Ashby who very kindly examined a culture of the fungus sent to him.

Summary.

A disease of antirrhinums causing collar-rot and wilt was reported from the Botanic Gardens, Ootacamund. A Phytophthora was isolated from the diseased plants.

The fungus was grown on a variety of media and inoculations were made with the fungus on antirrhinum plants. The plants took infection and the same symptoms as are seen in nature were reproduced. Inoculations on other plants known to be hosts of Phytophthora were not successful.

Sporangia are produced but rarely in agar cultures but they are formed in plenty in water.

Oospores are found in numbers. Both amphigynous and paragynous antheridia are present the latter being more common. The fungus has been named *Phytophthora pini* var. *antirrhini*.

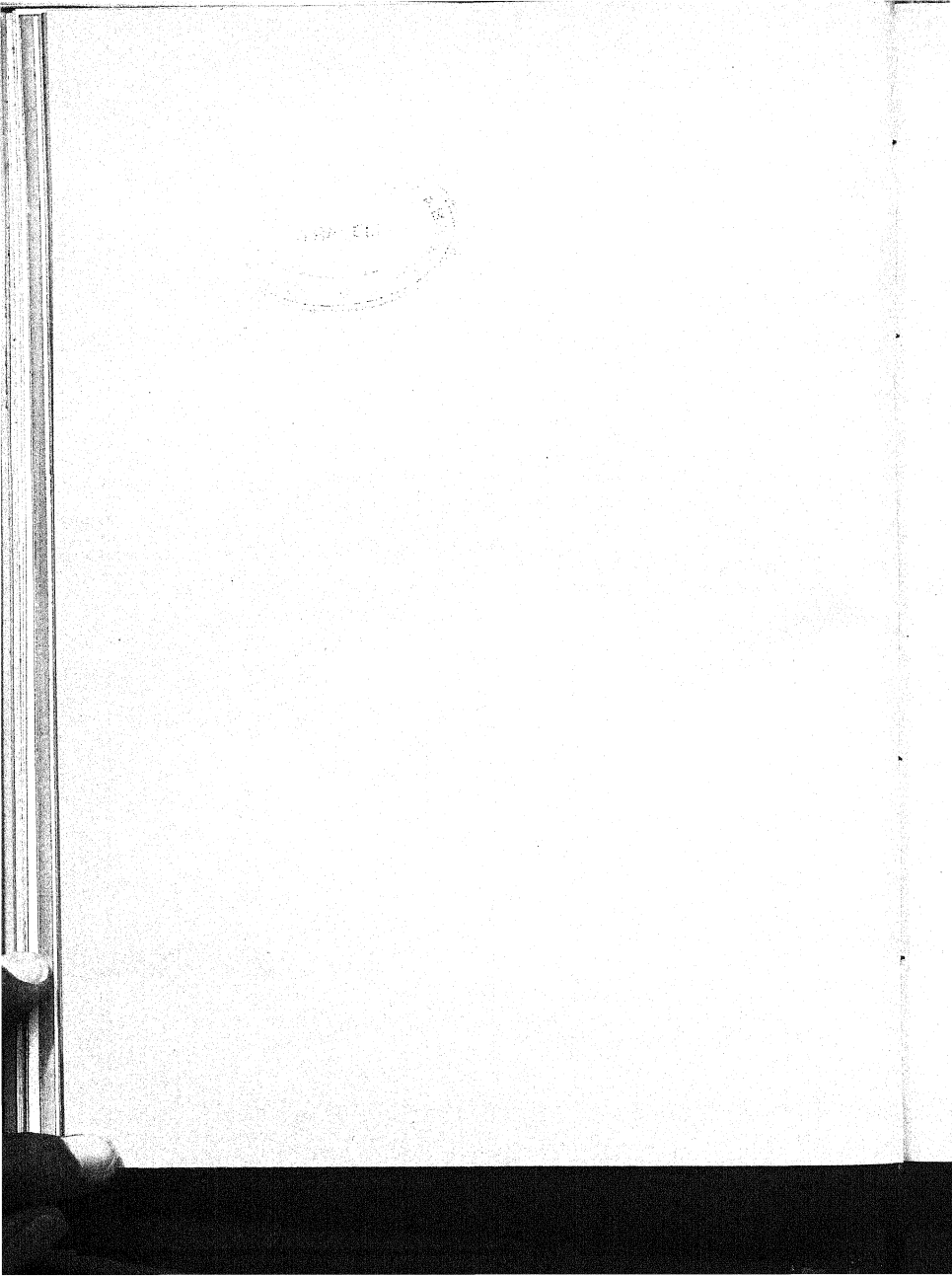
MGIPC—M—III-1-60—27-11-1928—650.

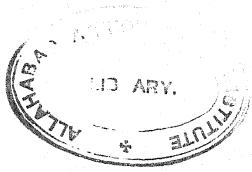
PREFACE

We have been greatly helped in our investigation of grasslands by various individuals and institutions. We wish to make special acknowledgment of our indebtedness to the officers of the Forest Department in the Bombay Presidency, to the office-bearers and members of the Bombay Gowrakshak Mandali, and to the officers of the Military Grass Farms in Poona.

W. BURNS
L. B. KULKARNI
S. R. GODBOLE

POONA,
May 7, 1928.





CONTENTS

FURTHER STUDIES OF INDIAN GRASSES AND GRASSLANDS.

BY

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(Received for publication on 19th May 1928.)

I. Introduction.

This memoir, which is the continuation of a previous one[1], is an attempt to give an account of investigations carried on from 1925 to 1928 on the grasslands of the Bombay Presidency. The fact is now definitely established, here, as in other parts of the world, that by comparatively simple measures the outturn of grass from any type of grassland can be considerably increased. The improvement of grassland by gradual natural change due to the dominance of better kinds of grass always takes place if excessive grazing and trampling are prevented, but this process of improvement is naturally slower in dry areas than in areas with plentiful rainfall. In the dry areas, however, if the soil moisture can be conserved, the grass tends to improve rapidly, so that we have here again a dry farming problem, to be solved in this case, not by ploughing and mulching, but by the use of low contour ridges, the prevention of erosion, and the use of the vegetation itself to prevent run-off. The improvement of the grasslands which we have been investigating offers real practical difficulties of an economic character since no control of the movement of animals on pasture is possible without fencing, and the present cost of fencing makes it an uneconomic proposition save on forest areas or on the best grasslands. The fact that a wide expanse of unfenced grassland, now roamed over by the cattle of a village, belongs to many different owners makes co-operative treatment of such

[1] Burns, Kulkarni and Godbole : A Study of Some Indian Grasses and Grasslands. *Mem. Dept. Agri. India, Bot. Ser.*, XIV, 1 ; 1925.

land very difficult. The problem must be solved somehow, sooner or later, and the present and preceding memoirs are contributions to our knowledge of the subject indicating from actual observation and experiment what changes *do* take place when grassland is treated in various ways.

It is unnecessary in this second publication to repeat in detail the account of the ecological conditions of the Bombay presidency previously given.

None of the three years above mentioned was a really bad year as regards rainfall deficiency. The distribution of good rainfall throughout the Presidency was in all three years rather uneven from place to place, some places being favoured and others not getting enough. The 1927 monsoon started late. From the point of view of grass production, the only great abnormality was the excess rainfall in Gujarat in September 1926 and July 1927. Otherwise the years may be considered normal for the Presidency as a whole, but in the Deccan there was very little rain in 1925, and in 1926 and 1927 the effective rains terminated abruptly in September. In 1927 there was rain in November that spoiled much of the cut grass.

Of the work which is additional to the investigations previously recorded, the following may be specially mentioned :—

(*a*) a large scale experiment on rotational grazing in the forest area of Bhamburda (p. 112),

(*b*) a similar experiment at Jalgaon (p. 118),

(*c*) a line survey from a station of low rainfall (Sirur) to a station of high rainfall (Lonavla) (p. 130),

(*d*) the study of the grass trade at its main centre in the Bombay Deccan (Talegaon) (p. 131).

These additional three years' work and observations confirm the previous statement that variations in grassland depend on soil moisture. Other outstanding points are the slowness of improvement of grasslands in areas of low rainfall and shallow soil, the marked difference between the same species on deep and shallow soil, and the great increase that can be got in total weight of grass from any area if it is forced to give its maximum yield by proper methods.

II. Grasslands in the Deccan.

Kalas.

It may be again mentioned that, at Kalas, an area of seven acres of the worst Deccan land has been under observation since its enclosure in 1920. The plot contains a dry hilly portion, a low-lying portion of good soil and a flat portion of poor shallow soil. Succession in the dry hilly portion was recorded as from poor grasses and *Commelinaceae* to *Aristida* species and *Andropogon contortus* and thence to perennial tussock grasses such as *Ischæmum laxum*.

In the low-lying area, with good soil, perennial grasses of a better type such as *Andropogon annulatus* succeeded *Andropogon contortus*. In the flat area of poor shallow soil, improvement was slow, the *Aristidas* and *Andropogon contortus* holding their own, and perennial tussock grasses only very gradually getting a foothold.

Spread of tussock grasses.

The effect of enclosure on the spread and development of perennial tussock grasses is shown by the figures obtained from careful measurements taken in July 1927. For the purpose of calculation each tussock was considered as circular, its radius measured at two inches from the ground and the area calculated therefrom. The method is rough, but no better method could be used without an expenditure of time disproportionate to the accuracy required. The area covered by tussocks was then expressed as a percentage of the area of the plot examined. These plots were quadrats of 15 ft. side in most cases, but where the tussocks were very few, a larger quadrat was used to get a more truthful expression of the facts.

The following are the results :—

Hilly portions.

Quadrats within enclosed area	Percentage of ground occupied by tussock grasses	Quadrats outside enclosed area	Percentage of ground occupied by tussock grasses
(1) Strip annually cut . .	2·67	(1) Flatter stony portion .	0·70
(2) Strip annually burned .	6·35	(2) Sloping stony portion .	0·81
(3) Untouched check strip .	5·62	(3) South-west portion .	3·81
* (4) South-west corner (cut and burned annually)	7·52	....	..
* (5) South-west corner (check portion)	9·39	....	..
Mean of the above five observations.	6·31	Mean of the above three observations.	1·77

Flat shallow portion.

† (1) Near the gate (untouched strip).	0·18	(1) Flatter portion . .	0·41
(2) Strip annually burned .	2·67	(2) Sloping portion . .	0·33
Mean of above two observations	1·42	Mean of above two observations.	0·37

* A corner where growth of perennial tussock grasses has been very vigorous.
† A bare open area where tussock grasses have got little hold.

Low portion with deep soil.

Quadrats within enclosed area	Percentage of ground occupied by tussock grasses	Quadrats within enclosed area	Percentage of ground occupied by tussock grasses
Strip annually burned . .	9·72	North end	9·20
Strip annually cut . .	11·24	South end	5·47
Mean of the above two observations.	10·48	Mean of the above two observations.	7·33
Mean of all the observations within the enclosed area.	6·15	Mean of all the observations outside the enclosed area.	2·96

It will be noted that these measurements were taken at two inches above the soil. When the stumps are in full growth and flower at the end of the rainy season they appear to occupy a very much larger proportion of the area and hence our somewhat optimistic previous estimate of the area covered.

The main points to note are :—

(1) Outside the fence, with the perpetual grazing to which they are subject, these perennial grasses get no chance to develop. They are present, however, and only need encouragement in order to develop.

(2) Sloping land with a fair sprinkling of rocks and stones gives a better stand of stumps than flat or sloping land that has no stones on it. There appear to be two reasons for this,

(*a*) the stones act as a mulch and serve to retain moisture,

(*b*) the seedlings get mechanical protection from run-off. (Pl. I, figs. 1 and 2.)

Effect of drain.

In the low-lying area of good soil, water tended to stagnate at one end, near the boundaries of the Kalas plot. The effects of this on the vegetation were—

(1) the species tended to be hygrophytic,

(2) a film of blue-green algae appeared and remained on the surface of the soil,

(3) the foliage of the tussock grasses was reddish in colour.

In 1924 a drain was cut through this area. It was a ditch two feet broad and varying from one to three feet deep and led outside the fence.

In 1925 the vegetation had no hygrophytic elements in it whatever, but this was partly due to the scanty total rainfall of the year (14·47 inches). In 1926 the precipitation was about normal, being 21·76 inches. Some of the hygrophytic elements

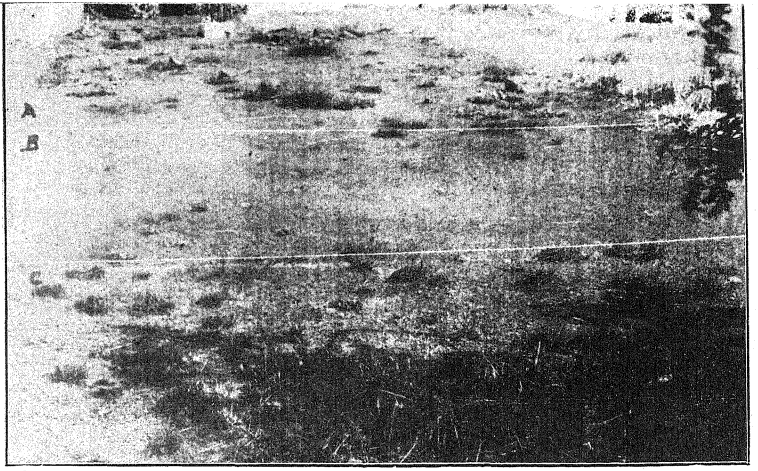
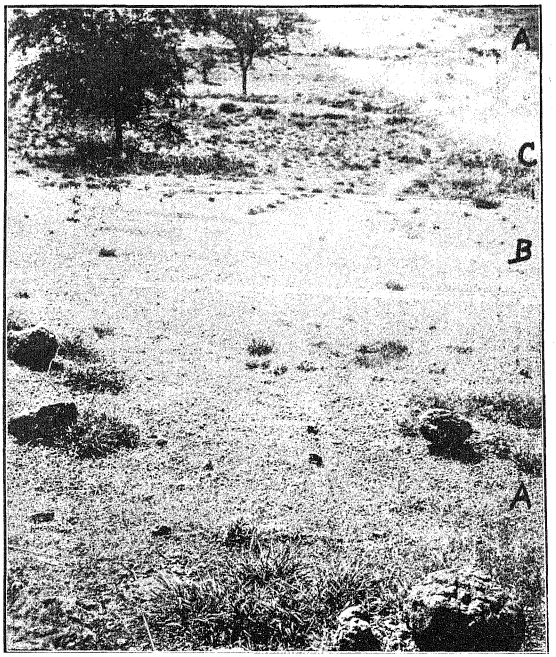
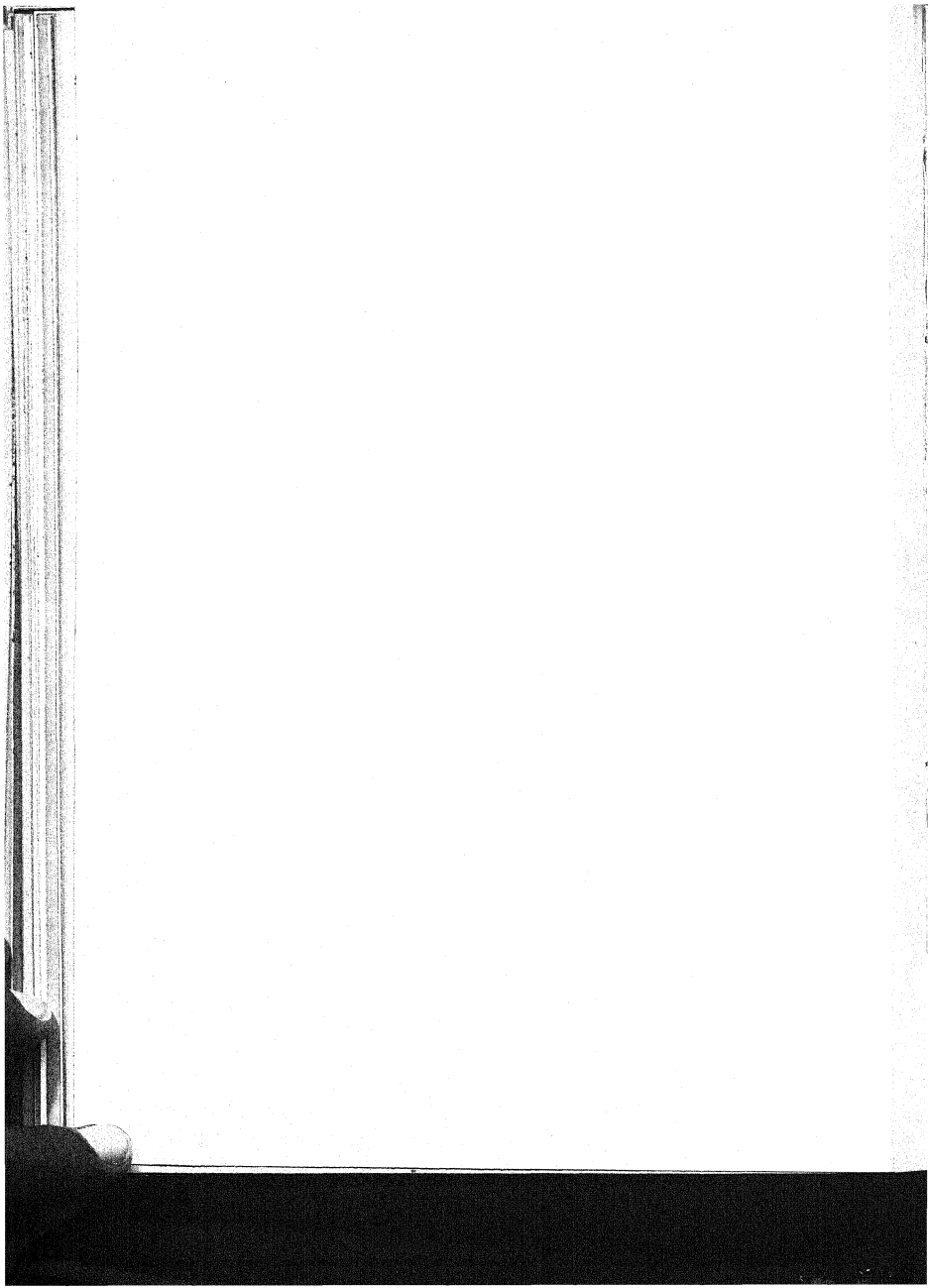
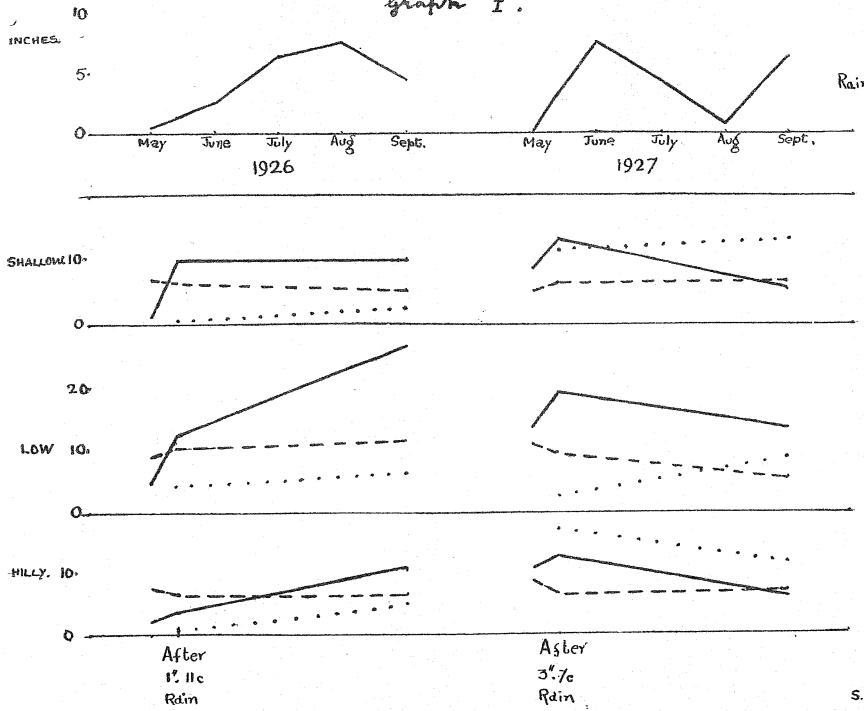


Fig. 1. *A*, showing area with scattered perennial grasses; *B*, Flat shallow area with no perennial grasses; *C*, low area with many perennial grasses.





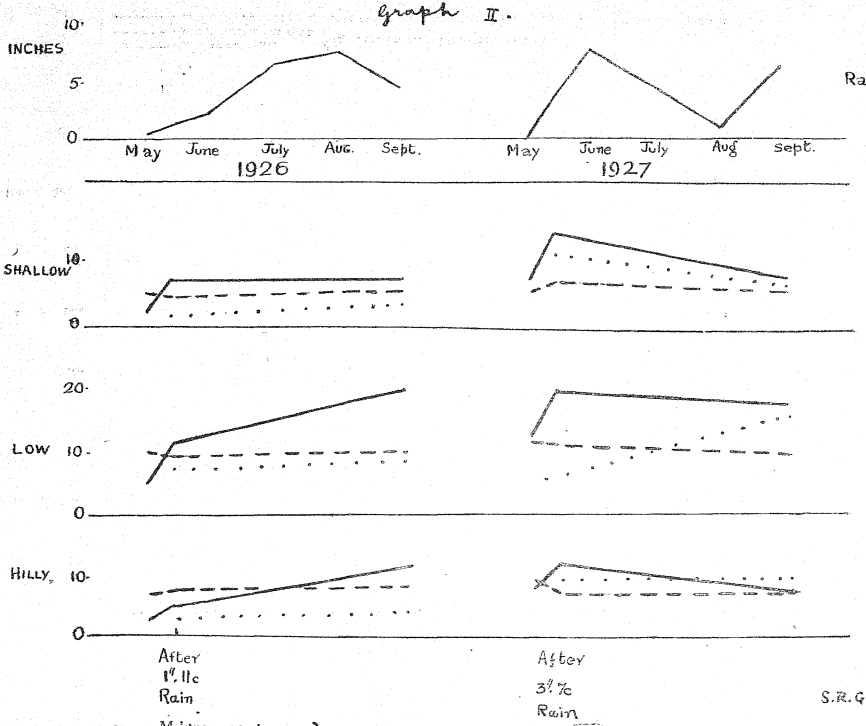
Graph I.



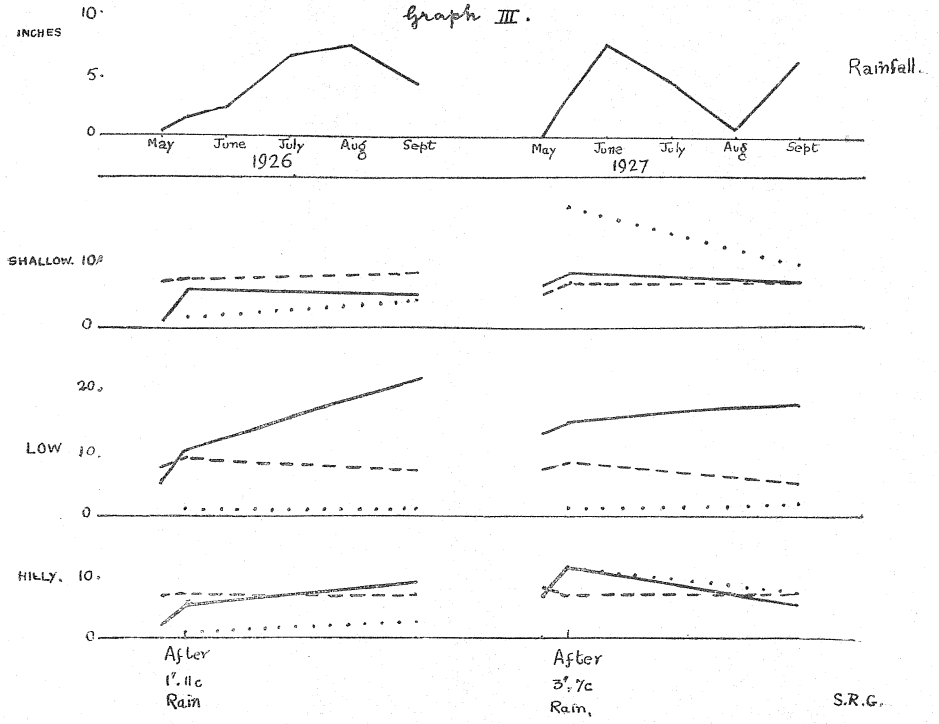
S.R.G.

——— Moisture per cent.
- - - - - - Organic Matter per cent. } from the *enclosed unburnt* area at Kalas.
. . . . . Plant Population per sq. metre in *hilly* and *shallow* areas and space occupied by stumps (in sq. cm.) in *low* area.

Graph II.



——— Moisture per cent.
- - - - - Organic Matter per cent. } from the *enclosed burnt* area at Kalas.
– – – – Plant Population per sq. metre in *hilly* and *shallow* areas and space occupied by stumps (in sq, cm.) in *low* area.)


Graph III.
INCHES
10·
5·
0
May
June
July
Aug
Sept
1926
1927
Rainfall.
SHALLOW. 10
0
20
LOW 10
0
HILLY. 10
0
After
1", 11c
Rain
After
3", 7c
Rain.
S.R.G.
Moisture per cent.
Organic Matter per cent.
Plant Population per sq. metre in hilly and shallow areas and space occupied by stumps (in sq. cm.) in low area.
from the unenclosed area at Kalas.

such as *Fimbristylis* and *Eriocaulon* reappeared but were in small quantity while plants definitely not hygrophytic, such as *Pulicaria wightiana*, made their appearance. There was in 1925, 1926 and 1927 no appearance of the unhealthy red colour in the leaves of the tussock grasses.

The drain seems to have been rather too effective at some places. In quadrat No. VI, for example, *Indigofera trita* is now dominant in a plot where *Andropogon annulatus* was previously the main species. *Aristida redacta* and *Tripogon Jacquemontii* are also making their appearance, sure signs of a deficiency of soil moisture. The drain, moreover, tended to be badly eroded by the falling in of its sides which the local grasses failed to bind. It therefore appears that the digging of a drain in a deep-soil grass area is an operation that needs to be done (if done at all) with very considerable caution, and that probably a better way of treating the ground would be to divert by some outside channel the surplus water, and to leave the area of good soil untouched.

Effects of burning.

In the previous memoir mention is made of an experiment to compare the effects of burning, cutting and grazing along with check plots. A fuller account of this experiment may now be given.

From end to end of the Kalas plot covering the most representative portions of the middle of the plot, we laid out six equal strips, each 30 ft. broad and 925 ft. (the complete length of the plot) long. Every alternate strip is an untreated check strip, and of the others one is burned annually in February, one is burned annually in May and one is cut in November. The idea of grazing was given up as there was no room for it. The above treatments have been given, the cutting five times, *i.e.*, from 1923 to 1927, and the burning four times, *i.e.*, from 1924 to 1927. In the case of the first two burnings the standing grass was burned just as it was. In the second two burnings the grass was cut first to estimate the yield and the stumps burned. Where stumps were scattered, dry grass was spread and burned so that all the surface got the benefit of the heat.

We shall now summarise our observations on the several points studied in these strips :—

Tables I, II and still more Graphs 1, 2 and 3, which are made from these tables, bring out certain interesting facts.

It will be observed that the distribution of the rainfall in the two years 1926 and 1927 was very different. In 1926 the rainfall gradually increased until August and kept well up even in September. In 1927 the rainfall fell off after June and continued to do so until September when there was an increase, but this increase, so far as the graphs go, was too late to affect the soil moisture.

Comparing first the enclosed unburnt with the non-enclosed (also unburnt) areas, it will be observed that in 1926 the shallow area in the enclosed portion absorbed and held more water than the unenclosed part. In 1927 it absorbed more

water but at the end of the season was no more able to hold it than the unenclosed part. The low area, as was to be expected, in 1926 absorbed and held much more than the unenclosed portion, but in 1927 it lost more towards the end of the season due to the action of the drain. The hilly area shows little difference in the unenclosed from the enclosed portion in either year.

There is little doubt therefore that in 1926 with the gradually increasing rainfall, the enclosed portion was much better off for soil moisture. This is also reflected in the plant population curve and in the organic matter curve of the shallow and low parts. In 1927 the enclosed areas started well with a higher absorption of water than the unenclosed, but the poor later rains did not continue to maintain this reservoir of soil water and the vegetation *plus* evaporation rapidly decreased it to about the same as the unenclosed.

Within the enclosed part, comparing the unburnt with burnt portions we see that in 1926 the unburnt portion scores over the burnt so far as the shallow and low areas are concerned, but that there is little difference in the hilly area. In 1927 there is little difference between the unburnt and burnt portions in any area, though the shallow area seems to have *absorbed* slightly more, and the low area to have *retained* slightly more moisture in the burnt portion.

In the shallow and hilly areas both organic matter and plant population are less in the burnt portion but in the low area the organic matter and plant population are more in the burnt portion in 1927 with little difference in any area in 1926.

Generally speaking, then, burning in the case of all areas has been a disadvantage from the point of view of absorption and retention of soil moisture in 1926, while in 1927 there is little difference.

As regards water penetration, the enclosed portion permits of much more of this, while the burnt areas, on the whole, allow of more water penetration than the unburnt.

In considering the effects of the various treatments on the individual strips we have had to express the results in several other tables. Of these the most striking is that showing the grass yield in the various strips (Table III). In the cut strip the gradual and continued increase is the most striking thing.

Burning in February has in no way reduced the amount of grass produced, but burning in May has done so in both years.

Table IV shows the number of spikelets produced on five plants taken at random in the hilly, low and shallow areas in all strips, for two species. The large numbers of spikelets in the burnt strips are specially noticeable.

As compared with plants outside (Table V), the species within the enclosed area show a large increase in number of spikelets.

Table VI deals with the plant population and area occupied by stumps in all strips and also outside in the years 1926 and 1927. The chief interest of this table is in the clear indication it gives of the large part covered by perennial grass stumps in the low area, and in the marked increase in the area covered by such stumps

in a year's time in all areas where these stumps occur. As regards stump production, the February-burned area seems to be the best.

Table VII shows the relative numbers of grass and non-grass plants in a metre-quadrat in each strip and in each area. The results indicate that non-grasses are ousted and grass plants increase in the cut and burned strips.

Summarising, then, all that we have been able to determine regarding burning, we may say that, on the whole, it tends to allow of deeper water penetration, but does not tend to the holding of water. In the case of low areas with a fairly good water-content and a population with a fair number of stumps, burning in February is not detrimental and may, indeed, be beneficial if one is to judge from the stump population and the increase in number of spikelets. May burning is not so useful. In the case of the shallow areas burning seems definitely detrimental to both soil moisture and plant population and in the hilly area neutral. Cutting and burning have both increased the grasses at the expense of the non-grasses.

Effects of transplanting stumps of perennial grasses.

It has already been mentioned above that tussock grasses were slow in invading flat or sloping areas of poor lands which were lacking in scattered surface stones. In order to see whether these tussock grasses would make headway if artificially established in such flat or sloping non-stony areas, stumps of *Andropogon Monticola* and of *Ischæmum laxum* were transplanted into such areas in July 1924, and August 1925. Of the first set of 32 stumps, seven survived. They flowered and seeded in the following season and are now firmly established. In the second set 168 stumps were planted out of which 120 are now surviving. Out of these, 68 of *Ischæmum laxum* and 35 of *Andropogon Monticola* have flowered and seeded and all are firmly established. This clearly proves that it is perfectly possible to increase the stand of tussock grasses by artificially transplanting them and that once they get a hold they are not overcome by the grasses already on the spot, but on the contrary proceed to grow and to produce seed.

Experiment to establish tussock grasses by sowing their seed.

In the flat area where no tussock grasses exist, two metre-quadrats were marked out. A boundary of small stones (about two inches diameter each) was placed round one quadrat and the other was left without a stone boundary. In each quadrat 600 seeds, made up as follows,

200 *Andropogon contortus* (perennial),
200 *Andropogon Monticola*,
200 *Ischæmum laxum*,

were scattered. No treatment was given to the quadrat and the seeds were merely strewn on the surface of the soil.

Observations in future seasons will show how these seeds behave and will give us an idea whether stumps established by transplanting will be able to multiply their kind by their own seeds.

Results of quadrats.

As has been described in the previous publication, six single metre-quadrats were charted in 1920. In 1921 a burned and a scraped quadrat were added beside four of these, and a scraped quadrat beside one other. One remained without any additional quadrats. Counts were made yearly of the total number of plants present and of the number of species present, the counts being made in November. The previously given tables (up to 1924) are here repeated along with three more years results. See Tables VIII and IX.

The following are the conclusions reached as regards the last three years :—

The fluctuations in number of plants are at first sight a little puzzling but deeper analysis reveals some points of importance.

Original quadrats. Quadrats I, II, III and VI show a drop, while quadrats IV and V show an increase in 1925. The two last quadrats are on flat non-stony land. 1926 was a bad year for all the quadrats with the exception of Group II. We think this is explicable. Group II is in conditions where there is always adequate, and sometimes excessive, soil moisture, and it has not been affected by the drain. The year 1925 was a bad monsoon and grasses suffered very badly producing very little seed except in such favoured spots. The result is seen in the following year when the stand is much smaller in all except the place where soil water was in plenty. 1927 shows a normal increase in all groups except in VI which has been over-drained, as has already been explained (see p. 105).

In 1927 in Groups I, III and IV the population is bigger than it has ever been before, in V it is practically identical with 1924, the best previous year. Taking a general average of all the original quadrats (except II), we can therefore state that in 1926 the plant population was 120·5 per cent. greater than the plant population of 1920 while in 1927 it was 362·8 per cent. greater than the population of 1920.

In II while the total number of plants is less, the individual plants, mostly perennials, have markedly increased in size.

These figures must be taken in conjunction with the yield results which show a striking increase in actual bulk of foliage produced.

Scraped quadrats. It must be kept in mind that these quadrats were scraped in 1921 and have not been touched since. They have thus had time to recover and there is now no difference between them and the original quadrats. Their behaviour corresponds closely to that of the original quadrats. Like the original quadrats these scraped ones show the same marked drop in the year 1925 except in the quadrats of Group II, thus confirming our explanation of that phenomenon. They are sometimes better and sometimes worse than the associated original quadrats

but their general lines of behaviour are explicable on the same lines, and the effect of scraping has certainly not persisted up till now.

Burned quadrats. Like the scraped quadrats these were treated once in 1921 and have not been touched since, and hence are also practically in the condition of the original plots, having now fully recovered from any effects of burning. Like the scraped quadrats they are sometimes better and sometimes worse than the originals but their general behviour is the same.

General conclusions. The effects of scraping and burning six years ago are now invisible. The two bad successive years 1924 and 1925 reduced the total plant population but this rapidly recovered with one good monsoon. The increase in plant population reached in 1924 due to enclosure has been maintained and in some cases increased. Along with this has gone the increase in bulk of individual perennial plants, the net result being an increase in the amount of vegetable matter produced. This is strikingly shown in the figures in Table III on p. 137 where the amount of vegetation actually cut has increased 350 per cent. in the years 1924-1927 in the cut strip.

Conclusions regarding change in number of species per quadrat.

The general conclusions reached are these :—

There is a big drop in the number of species in 1925, probably the first indication of the effects of the comparatively poor and badly distributed rainfall of 1925. Some species were much more affected than others and did not survive. This decrease is continued but not accentuated in 1926, and there is generally a slight recovery in 1927. The number of species present, however, does not come up to what it was in 1924 indicating that certain species have firmly established themselves during the bad years at the expense of the others. *Spermacoce stricta*, *Zornia diphylla*, and *Glossocardia linearifolia* have much decreased. These are plants of no fodder value.

Succession.

It will be desirable to deal with the various groups of quadrats separately and then attempt to come to some conclusion as to succession in general.

In the first group of quadrats there has been no progress beyond the condition in which *Andropogon contortus* (annual form) is dominant. This appears to be the sub-climax form of this type of ground. *Aristida funiculata* and *Tripogon Roxburghii* are subdominant in most cases and a year that is bad for *Andropogon contortus* gives them a chance to multiply and to become dominant.

In the second group, *Iseilema laxum* holds its own and seems to be the sub-climax form. *Andropogon annulatus* is present in fair quantity but does not appear to be increasing, on the other hand there is a tendency for it to decrease. *Apluda varia* has increased. Plants that are swamp-lovers such as *Fimbristylis complanata*

come and go according to the nature of the season and the amount of water-logging. In 1927 the original quadrat was dominated by the non-grass plant *Canscora decurrens* which is a hygrophyte. This and similar plants grow in the gaps between the perennial tussocks and do not interfere with them.

The third quadrat, of which there is only one, has shown steady progress. It began as very nearly sheer rock with a little dust on it, and after passing through stages in which *Cyanotis fasciculata* and *Gracilea Royleana* were dominant now seems to have arrived at the *Andropogon contortus* (annual) stage, this being probably as far as it will get. It is interesting to note however that *Ischæmum laxum* has actually appeared on this quadrat and that *Zornia diphylla*, which was the dominant plant in the next quadrat group in 1920, is present.

The fourth group is dominated by *Aristida funiculata* with *Andropogon contortus* (annual) a close second. The perennial grasses *Ischæmum laxum* and *Andropogon Monticola* have, however, now got a footing.

In Group V, *Andropogon contortus* is dominant and *Aristida* species mainly *redacta*, but in some cases *funiculata* are subdominant. *Ischæmum laxum* has appeared in one of these quadrats only and there is no invasion of *Andropogon Monticola*.

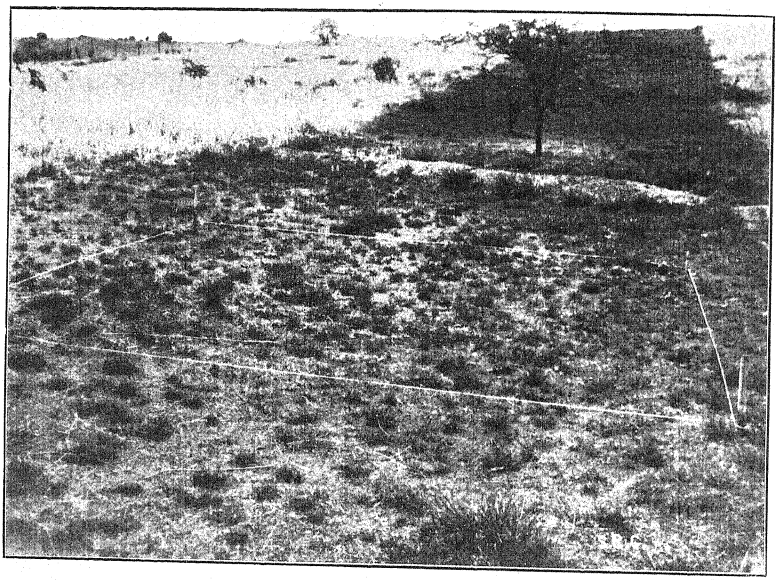
In Group VI there has been a definite decrease of *Andropogon annulatus* due to excessive drainage, and in 1927 there was a large invasion of *Indigofera trita*. The *Aristida redacta* and *Apluda varia* have increased considerably.

Conclusions regarding succession.

It is unfortunate that none of these quadrats represent typical portions of the hilly area where the tussock grasses now dominate. On this portion it is plain that the sub-climax condition is tussock grass consisting of *Andropogon Monticola*, *Ischæmum laxum*, *Andropogon triticeus*, and a little of the perennial *Andropogon contortus*. These are well established but are slow to spread, and we may assume that there will always be room between their stumps for the annual form of *Andropogon contortus*, for other poorer grasses and for many ruderals.

Quadrat Group I is a fair example of such land where tussock grasses have *not* got a hold, and it has not got beyond the *Andropogon contortus* stage in seven years. It is plain, therefore, that our hope of improving such an area depends entirely on the tussock grasses. This opinion is strengthened when we look at quadrat Groups IV and V. There too (on the flat poor area) the vegetation apparently will not progress beyond the *Andropogon contortus—Aristida* stage unless helped by tussock grasses, and fortunately these are invading the area as shown by quadrat IV. We may again refer here to the considerable success obtained in transplanting stumps of tussock grasses into this area. Once the plants get hold they can establish themselves and will stand up to severe conditions. The salvation of both the hilly and the flat areas of the Deccan therefore lies in such treatment as will allow of and encourage the invasion, establishment and growth of the perennial tussock grasses.

PLATE II.



First class of land dominated with tussock grasses.

Quadrat III is of interest only as showing the uninterrupted progress from mere rock to the *Andropogon contortus* stage and with a promise of tussock grass as well.

Quadrat groups II and VI show clearly that where there is plenty of soil moisture there the grasses *Andropogon annulatus*, *Iseilema laxum* and similar good species establish themselves to the exclusion of everything else. But this condition of things is unstable, and where the water content is interfered with by excessive draining the good grasses rapidly lose ground and xerophytic vegetation comes in. Swamp conditions influence the subsidiary flora considerably but do not seem to reduce the good species, though their growth may to some extent be interfered with. The moral is, that where there is good soil with a fair water content, nothing should be done to disturb it, and it is better to risk some swampiness than to do anything that might reduce the water content of the soil.

III. Other Stations in the Deccan.

The various stations mentioned in the first memoir have been revisited. We have come to the conclusion that it is better to classify the sub-climax grasslands into three classes instead of two.

Table X clearly indicates this. The first class of land tends to be dominated by tussock grasses (Plate II), the second by *Andropogon contortus* (annual) and the third by *Andropogon annulatus* and similar good grasses. The average soil moisture in the first two classes is small, but where one gets a case of a higher soil moisture in these classes then the result is seen at once in the species produced.

The Work of Ants in Deccan Grasslands.

Ants may prove to be an important biotic factor in the grasslands of the Deccan. We are not at this stage quite sure whether they are beneficial or harmful, and the following observations are put down as a first contribution to this branch of the subject. We refer to ants proper (in the present case *Holcomyrmex scabriceps*) and not to white ants or termites.

The * observations were made at Kalas, where about 100 nests were opened. These are easily visible on account of the heap of glumes and awns of grasses on the soil above them. The places selected for such nests are generally places where the vegetation is sparse either on account of bad germination or burning. The total area of a nest may be 3 square ft. It consists of a series of burrows running from 4 to 9 inches below the surface and with numerous openings on the surface. Long lines of ants up to 30 ft. long are found moving to and from these nests especially after rain bringing grass seeds which they have collected. We have not observed the actual removal of glumes and are not sure where it takes place, but presumably it is done just before taking the cleaned seed down into the burrow.

* Godbole, S. B., and Deshpande, R. B. Ant Burrows in Grass Areas. *Poona Agri. College Mag.*, XIX, 4; February 1928; pp. 213-215.

In the burrows we found seeds of different species stored separately in separate compartments, although there were rare cases where the seeds of *Andropogon contortus* and *Aristida funiculata* had been mixed. The species actually stored were :—

Andropogon contortus
Andropogon purpureo-sericeus
Aristida funiculata.
Indigofera linifolia.
Zornia diphylla.

It will be observed that the ants do not confine themselves to the *Gramineæ*.

It is not definitely known what the ants do with these seeds but, if they eat them, then they are to that extent destroying the means for the multiplication of the plant. On the other hand, if there is much uneaten residue then there is at that place a patch of seeds that should result in a clump of that species springing up and this is what does actually often happen. Whether the production of these clumps or the reduction of scattered growth of the species over a greater area is the more effective ecologically still remains an unsolved problem.

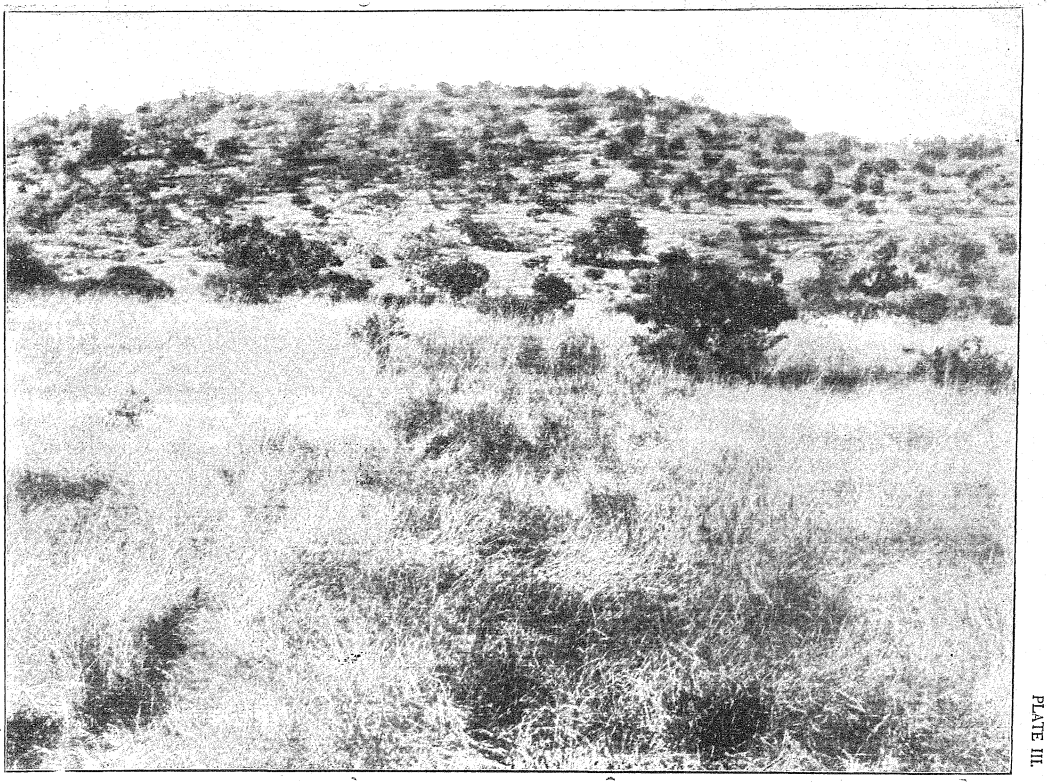
IV. Experiments in rotational grazing and cutting.

In the present paper the writers do not propose to go over again the general conditions of grassland in the various parts of the province, but to confine themselves to the description of experiments carried out in different parts of the province. These experiments are on similar lines with modifications to suit local conditions. Briefly their object is to study the effect of an arbitrarily devised scheme of grazing and cutting in different climatic and edaphic conditions.

(*a*) Bhamburda.

In order to follow up the Kalas results and to put in practice some of the suggestions got from observation in America and from American literature, an area was secured for a period of years from the Forest Department, at Bhamburda near Poona, in June 1925. This area is at the base (on the northern side) of a low range of hills of from 120 to 250 ft. above the level of the surrounding country. The accompanying map indicates generally the lie of the land and the distribution of species on it and the photograph is taken from a point near the foot of the hills in block IV and facing the hills (*i.e.* facing west). The area in question is in the middle of the picture. (Plate III.)

Plate IV gives the outline of the area, its subdivision into plots, the amount of ground of a hilly nature, and the various soil types. The total area is forty acres



Bhamburda grazing area showing the hill slopes and low plains with vegetation.

PLATE III.

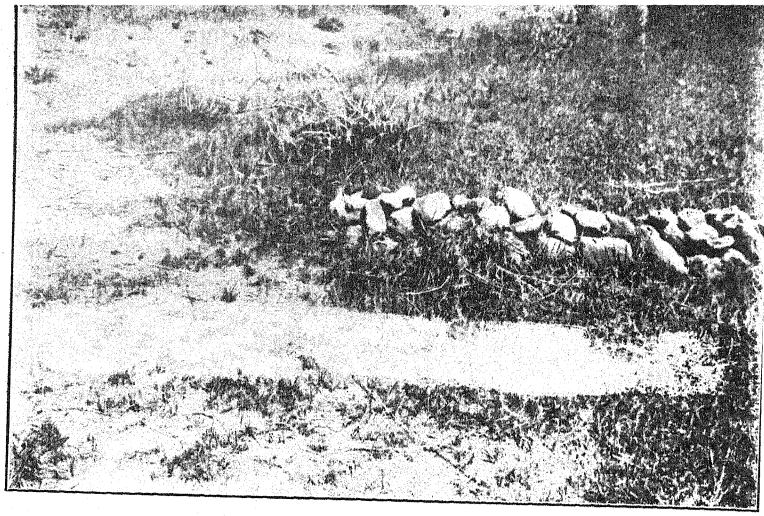
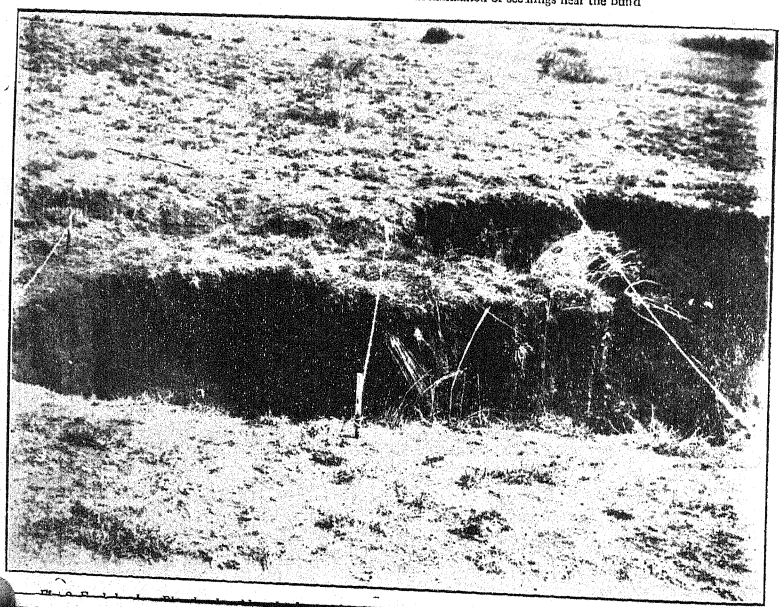


Fig. 1. Low contour bund. Note the accumulation of seedlings near the bund



and is divided into four equal blocks of 10 acres each. An outside fence enclosing the whole area was erected before the start of the experiment, but internal fences dividing one block from another were finished only in August 1926. This delay was due to lack of funds.

The area resembles that at Kalas with the exception that it is nearer a hill. The area also has had the advantage of a sort of protection for about twenty years during which it has been enclosed and trees have grown. The tree growth, however, is sparse and open as will be seen from the photograph.

The dominant tree is *Boswellia serrata*, and there are scattered specimens of several other species such as :—

Acacia leucophlœa, Bauhinia tomentosa, Rhus mysorensis, Odina Wodier, Flacourtia Ramontchi, Cochlospermum Gossypium, Anogeissus latifolia, Terminalia tomentosa, Gymnosporia montana, Zizyphus jujuba, Zizyphus œnoplia, Zizyphus xylopyra, Azadirachta indica, Santalum album, Osyris arborea, Tectona grandis, Heterophragma Roxburghii, Stereospermum chelonoides, Dolichandrone falcata.

So far as the grass is concerned, it had been heavily grazed annually from 15th August to the end of October and lightly from November to February inclusive by an unlimited number of animals. It had been closed annually from March to August 15. The area was burned accidentally almost every year.

The soil types vary from mere gravel on the top of rock to deep medium-black soil, which, so far as one can judge from the section exposed in nalas, is up to 5 ft. deep. Rainwater coming from the hill has eroded this deep soil into formidable nalas. The dominant grass was *Andropogon contortus* (annual), with the presence of tussock grasses just indicated and with a change of species to *Andropogon annulatus* and *Iseilema laxum*, where the soil become deeper. Plate IV shows block by block the distribution of the original vegetation. In 1926, before the rains, low contour* bunds of an average height of six inches were made of the local stones across all areas where there was any indication of wash or flow in the rains (Pl. V, fig. 1).

The first idea was to graze a herd of animals in one block after another and see how long they took to finish the feed in each block and whether it was possible to keep them in health on the grass alone. The first year of the experiment was not a good one for rain, and grazing could not be started till the beginning of August 1925. At that time 12 animals were grazed (four bullocks, three cows, two bulls, two calves and one buffalo). They were first put into block I and were attended by a watchman, there being then no internal fencing between the blocks. The animals occasionally strayed out of the block in which they were supposed to be grazing but on the whole were kept within the boundaries of the block. From August 21 there

* Bund = embankment.

were only 11 animals and from January 7 there were only 7 during that year. The animals grazed the blocks as follows :—

I. August 3 to August 31.
II. September 1 to November 11.
III. November 12 to December 14.
IV. December 15 to January 31.

The weights of the animals were not taken in this experiment, but, on the whole, so far as could be judged by observation, the animals improved in condition. There was no grazing at all from January 31 until August 4, 1926.

In 1926 the internal fences were complete and hence the experiment could be carried out under better conditions. The plan of the experiment was modified to the following :—

Block I.		Graze all the year round annually.
Block II.	1926.	Close till August 15 and graze from August 15 to June 1, 1928.
	1928.	Close from June 1 to August 15, 1928.
Block III.	1926.	Close till August 15, and graze till May 31, 1927.
	1927.	Close till August 15, and graze till May 31, 1928.
	1928.	Close till August 15, and graze till May 31, 1929.
Block IV.	1926.	Close till October 30, cut the grass in November. Graze thereafter as long as there is any available grazing.
	1927.	Close till August 15 and graze till May 31, 1928.
	1928.	Close till August 15 and graze till May 31, 1929.

As will be seen, Block I was to find out the effect of all-the-year-round grazing. Block III was to determine the effect of an annual closing while the young grass was growing. Block II was to see the effect of such a closure in alternate years, and Block IV to see what the land could produce in the way of hay, with grazing thereafter.

The number of animals used was at the rate of one animal to two and a-half acres.

To ensure a local water supply a bore was sunk at a point located by the Water Diviner to Government (Major Pogson) and a hand-pump installed on the bore. Rock salt was also according to the American practice strewn in the blocks.

What actually happened was as follows :—

Block 1 was grazed continuously as follows :—

Periods	No. of animals
4th August 1926 to 6th January 1927	4
7th January 1927 to 14th April 1927	5
15th April 1927 to 4th June 1927	4
5th June 1927 to 29th February 1928	5

Block II was grazed as follows :—

Periods	No. of animals
26th August 1926 to 13th February 1927	5
14th February 1927 to 30th March 1927	3
31st March 1927 to 3rd June 1927	2
4th June 1927 to 5th June 1927	1
6th June 1927 to 30th June 1927	..
1st July 1927 to 29th February 1928	5

The delay in opening this block to grazing was due to the difficulty of securing animals. Two of these had to be sent away on account of foot-and-mouth disease on February 14, 1927. Two more animals about to calve were returned to the owners later. The remaining animal became wild and had also to be removed. From August 1926 to February 1927 (the really important period) the land was grazed by a full complement of animals, and similarly from July 1, 1927 to February 1928.

Block III was grazed as follows :—

Periods	No. of animals
26th August 1926 to 5th March 1927	4
6th March 1927 to 31st March 1927	2
1st April 1927 to 14th August 1927	..
15th August 1927 to 29th February 1928	5

The grazing on this block also started late on account of difficulty in securing animals. In March 1927 they had to be returned to their owners who required them for ploughing. Accidental fires occurred in February 1927, destroying much of the dry foliage, and so the block was entirely closed to grazing from April 1, 1927 to August 14, 1927, and then the full complement of animals again admitted. The closed period was a little longer than originally intended but otherwise the plan has been carried out.

Block IV. This block was closed till the middle of November 1926 (to allow seeds to drop) and the grass then cut. The yield was at the rate of 1,053 pounds dry grass per acre. It was found impossible to graze after cutting since no new growth appeared. In 1927 the block was closed till October 30 and the grass then harvested gave 2.053 pounds per acre (semi-dry). This was stacked for use in the hot weather. There was some secondary growth stimulated by rain in February 1928 and two animals were admitted to graze on it. They were kept in the block for fifteen days after which the feed was finished.

Effect on the cattle.

The cattle which had nothing to eat except the grass they ate while grazing or which was fed to them from the stack, gained in weight during both rains and cold weather in both years and lost during the hot weather. With the exception of the two cases of foot-and-mouth disease their health remained good. The fact

therefore emerges that two acres of this comparatively poor grass land will support one animal all the year round, provided drinking water and salt are supplied.

Grazing habits of the animals.

After the rains broke the animals first attacked the new tender foliage arising on the perennial stumps of *Andropogon Monticola*, *Andropogon triticeus*, *Andropogon pertusus*, *Andropogon foveolatus* and *Ischæmum laxum*. At this time they occasionally also grazed tender plants of annual species such as *Gracilea Royleana*, *Eleusine ægyptiaca*, and *Andropogon contortus*, but the cattle often uprooted the plants, and disliking the earth getting into their mouths, ceased grazing these annuals.

After the cattle had grazed the perennials fairly hard they then attacked the tall well-established annual grasses such as *Iseilema anthephoroides*, and *Andropogon pumilus*. They also ate the tops of *Pulicaria wightiana* (*Compositæ*) and *Lavandula Burmanni* (*Labiatæ*). When the *Aristida* species and *Andropogon contortus* had produced their "spears" in November, the perennials were attacked a second time, only the tips of the shoots being eaten. Vegetation under the shade of trees and also vegetation on contour bunds was more closely grazed than vegetation elsewhere. Both these sites have more delicate foliage. The perennials continued to be grazed in the dry season as long as they showed any green leaves, and at this period also the cattle at last began to eat the now dry material of the annual grasses, doing their best to render it palatable by a free recourse to the rock salt provided. When all kinds of grass were nearly finished the animals ate also tree leaves and pods of *Acacia arabica* and *Acacia leucophlœa* and tried to force their way out of the enclosures.

In the cold weather the animals drank twice a day, once about noon and again about 5 P.M., and absorbed about 3 gallons each per day. In the hot weather they drank 3 or 4 times a day, and totalled 6 gallons each. During the rains they drank from nalas here and there and their drinking habits were not so regular. The bore on the site gave 26·3 gallons an hour in April of 1927, and 46·5 gallons per hour in February 1928 and hence was adequate for the number of animals we were using.

It is worth while adding a word or two on the use of salt in these grazing experiments. Salt is given in rations to milch animals, working bullocks and calves but the use of rock salt on grazing lands is unknown in Western India. In the United States of America*, however, it is an established practice, giving excellent results in the health of the animal and increasing its digestive power. We therefore started the practice in the Bhamburda experiment. At first the animals avoided the salt. When coaxed to lick it, they began to like it and in two months time were found licking the salt before and after grazing, in some cases continuing to lick for half an hour continuously. We have also found one aggressive animal monopolising

* Chapline, W. R., and Talbot M. W. The Use of Salt in Range Management. *U. S. Dept. of Agri. Circular* 379, July 1926.

a salt block while the other animals stood in a bunch waiting their turn. On another occasion when the watchman shifted the salt blocks from one place to another the herd followed him. The placing of salt beside rank coarse dry growth in January 1928 undoubtedly led to its being eaten. Each of our animals consumed on the average eleven ounces of salt a month from November to the end of February. Jardine and Anderson* state that each animal should have one to one and-a-half pounds of salt when grazing on dry grass. The use of salt also leads to the animals drinking more and this also probably helps greatly in the utilisation of the dry grass.

Effect on the Vegetation.

Three one-metre quadrats were charted in each block (I, II and III), *i.e.*, 9 quadrats in all. The following figures indicate increase in number of species and in area of perennial stumps in one year. Each figure is the average of the three quadrats.

	Plant population per sq. metre	
	1926	1927
Block I.	1,081	3,379
,, II.	683	3,687
,, III.	1,504	2,858
	Area of stumps in sq. cm. per sq. metre	
Block I.	99	263·3
,, II.	72	84·5
,, III.	142·2	284·6

These observations were made in July and August.

	Yield from Plots 4 × 4 ft. each (taken in November)	
	1926	1927
Block I.	1·12 lbs.	4·33 lbs.
,, II.	0·83 lbs.	3·16 lbs.
,, III.	1·87 lbs.	7·16 lbs.
	Yield per acre.	
,, IV.	1,053 (dry)	2,053 (semi-dry)

There appears therefore to be already an improvement in the vegetation, but too much weight must not be given to two years' results. The facts, however, remain that the vegetation has not deteriorated and the cattle have been well nourished.

* Jardine, J. T., and Anderson, M. Range Management in the National Forests. *U. S. Dept. of Agri. Bull*, 790 ; 1919.

It should be mentioned that the blocks grazed were grazed hard and clean except under thorny bushes, and hence the maximum use of the vegetation was secured.

Block IV which was cut in both seasons gives a yield of dry grass that is fair for this type of ground, but no after-growth for grazing unless there are late rains. It remains to be seen (1) whether grazing or cutting is the most economical way of using these areas and (2) whether the vegetation of the grazed and cut areas shows a marked difference later on.

Erosion.

The land, often of good quality, at the base of Deccan hills, is generally badly eroded, being cut up by formidable nalas (=gullies). One such nala occurred in the land under experiment at Bhamburda and, when we took over the land in May 1925, was about ten feet deep, fifteen feet broad and 112 ft. long. It has developed in deep black soil. It was photographed in successive years and the increased erosion measured in 1926-27, and 1927-28. In 1926-27 erosion extended back 8·75 feet, with a breadth of 12 ft. and a depth of 8·25 ft. In 1927-28 it had further developed by 2·25 ft. in length, 3·5 ft. in breadth and 3 ft. in depth. (Pl. V, fig. 2.) Arrangements are now made by properly placed bunds to divert as much as possible of the water that originally streamed down this nala and spread it out over the slopes of the grass-land. The effects of even small contour bunds are marked in preventing run-off, and this has been proved by an investigation of moisture penetration (the average of 12 samples in each case) in bunded and unbunded areas on June 26, 1927 after 6 inches of rain had fallen. The penetration in the bunded area was 4·2 inches while that in the unbunded area was only 3·6 inches. These small bunds stop a great deal of soil and in a couple of years many of them had to be heightened as the silt had risen to their original height. This silt carries a rich early vegetation much stronger and higher than that outside the bund and much relished by cattle. These small contour bunds, therefore, not only check erosion but add markedly to the amount of green feed immediately available.

(*b*) JALGAON (*Khandesh*).

An attempt was made to duplicate the Bhamburda experiment at Jalgaon in West Khandesh District. The area selected for this had for twenty years previous to 1912 formed part of a permanent grass *kuran*, in charge of the Forest Department (in whose custody it still is) and was closed to grazing. In 1912 it was thrown open to all-the-year-round grazing. During the period when it was closed to grazing, sparse thorn forest consisting of *Acacia arabica*, *Acacia catechu* and *Mimosa hamata* had sprung up along with scattered plants of *Butea frondosa*, *Bauhinia racemosa*, *Grewia tiliæfolia*, *Diospyros embryopteris* and *Zizyphus jujuba*. The area selected for the experiment consists of 44 acres. This was fenced and divided up by fences into four blocks measuring respectively 10, 9, 10·7 and 14·3 acres. The annual rainfall

averages 29 inches. The place is 884 ft. above sea level and is uneven as to soil and surface. There was a difference in species between the higher and lower parts of the area. In the higher part the perennial species *Andropogon Monticola, Andropogon foveolatus, Andropogon schœnanthus* and *Andropogon triticeus* were dominant, while in the lower part *Andropogon annulatus, Andropogon pertusus* and *Ischœmum pilosum* were dominant. The plan of grazing was to have been similar to that followed in Bhamburda, but many difficulties cropped up (intensified by the distance of this station from our headquarters), and the system was not adhered to. Briefly the results are these. In 1925 grazing started in September and was carried out with eight animals in Block I, from September 5 to October 21 and in Block II, from October 22 to December 8. Blocks III and IV were cut, the amount got being at the low rate of 320 lbs. dry grass per acre. This low result was partly due to careless harvesting, much of the grass having been left uncut. In 1926, with one animal per three acres, grazing was started on Block I on July 26 and on Blocks II and III on August 21. These three blocks were grazed up to April 15 after which stall feeding with hay was begun and continued up to May 18 when the animals were returned to their owner. In 1927 grazing began on Block I on July 23 and on Blocks II and III on August 29, with one animal to 2·2 acres. The animals were in good health till the end of February 1928. Thereafter they were stall-fed with hay from Block IV but lost weight. Block IV harvested in December 1926 and December 1927 gave an average of 738 lbs. per acre in each year. There was no secondary growth after cutting and hence no grazing.

Hot weather grazing could not be done for lack of shade and water. The results generally indicate that one animal to 2·5 acres can be grazed from July to February, but thereafter the animals must be otherwise fed. The yield of the cut grass is very low.

(*c*) CHHARODI (*Gujarat*).

In 1925 four adjacent areas each of approximately three acres were selected. A wire fence was erected round the outside of the twelve acres and each three acre block was separated from its neighbour by a fence of babul branches. The plan of the experiment was to try rotational treatment as follows :—

Block I. Graze from July to September.
Block II. Graze from October to December.
Block III. Graze from January to March.
Block IV. Cut in September, either feeding the cut material at once or putting it in silo, and grazing the cut area from April to June.

Two tubs of drinking water were supplied and rock salt was provided. A boy was employed to watch the animals.

The above scheme has not in any year been carried out as originally intended, due mainly to weather conditions. In 1925 two animals were used (*i.e.*, one animal

per one and a half acres) and grazed in Block I from August to October, Block II was grazed from November 1 to February 15, 1925 to utilise the vegetation more effectively. Block III was cut in November and gave 6,610 lbs. semi-dry stuff (*i.e.*, 2,210 semi-dry grass per acre). Block IV harvested in September gave 8,234 lbs. fresh grass (*i.e.*, 2,744 lbs. per acre). Blocks III and IV showed no secondary growth after cutting so the animals were fed on dry grass without concentrates until the end of March but as they were losing weight concentrates were then given.

The experiment therefore resulted in Blocks I and II being grazed and III and IV cut. The grazed blocks were not by any means completely grazed and about 50 per cent. of useful foliage of *Andropogon annulatus* and *Iseilema Wightii* was left untouched, indicating that the plots were understocked.

In 1926 it was proposed to put one animal to every three-acre block and to follow the Bhamburda programme. Hence one animal was let into Block I on July 22 and one animal into each of Blocks II and III on August 15. Block IV was harvested in September, all the grasses being then in flower. Small quadrats (two per block, one in a poor area and one in a good area) were examined for grass population and yield. In August and September 1926 the rains were very heavy and water stood two feet deep over the blocks for some days. The total rainfall for the season was 54·38 inches, the average being 30 inches.

Much trampling of grass resulted and puddling of land. Only the green parts showing above water were eaten, and much vegetation was left unused. After cutting there was again no secondary growth.

In 1927 Block I was opened in the middle of July and two animals were let in. They had to be removed for a time during the floods at the end of July and were re-introduced in August 4. Block II was under water for a long time and the animals could not be put in till September 17 while Block III was opened in the second week of August. Block IV was cut after the grasses had dropped their seed, the yield being 7,360 lbs. semi-dry grass.

Mention should be made of the unusual rains of this year. The total rainfall of the season was 103·90″ of which 73″ fell between July 24th and 29th. The area was flooded from 4 to 6 ft. deep.

From the actual experiment of rotational grazing and cutting we can draw few definite conclusions. The abnormal weather and the ineffectiveness of the internal babul fences forbid this, but we may make a few general observations.

(1) The area is a good grass area with the exception of a low-lying poor soil portion common to all blocks which is dominated by *Eragrostis cynosuroides*. The rest carried *Andropogon annulatus* and *Iseilema wightii* in about equal proportions as dominant species. These have proportionately increased during the last three years but this is probably due to the death of some of the lower growing poorer

species on account of two years flooding and especially the 1927 flooding. These poorer species which so suffered were *Chloris pallida, Aristida redacta, Andropogon contortus,* and *Indigofera cordifolia.*

(2) There is abundant feed for cattle in the early monsoon and one animal to one and-a-half acres is still too few. After cutting, however, there is no feed, unless in an abnormal flood year and hence it is hopeless to think of continuing grazing after cutting has been done.

The only point left to determine is how to get the maximum amount of grass off the area without causing the species to deteriorate.

Grasslands near Bombay.

(*d*) KANDIVLEE.

In the previous memoir we gave a brief description of the flora of Kandivlee, a station in the coastal area of the Bombay Presidency with a 90-inch rainfall and a consequently heavy growth of grass.

The area in question is part of the land of the Bombay Gowrakshak Mandali, a charitable organisation for the preservation and care of cattle, and in co-operation with this organization experiments in the management of this land were laid out. Unfortunately the complete fencing of all the blocks proposed was not carried out in one year and hence, previous to 1925 there are few data, and for 1926 only partial data. 1927 is the first year when the experiment was really in full swing. However, from all these years, the figures got are of importance, the more so as in an area of this kind of rainfall grass is a certain success.

An area of $6\frac{3}{4}$ acres was enclosed in 1923 and treated thus :—From June till the end of December no cattle were admitted, but a certain amount of the grass was cut for silage in August and the rest for hay in November and December. The increase in yield due to fencing only is shown in the following table:—

Year	Harvested semi-dry	Harvested green
	lb.	lb.
1923	21,000	*Nil*
1924	18,300	37,000
1925	27,000	55,000
1926	3,000	1,97,000

After the cutting of the grass in November and December all the animals of the Mandali (numbering 350) were admitted for grazing.

In addition a second block of 11 acres was enclosed as part of a scheme whereby five blocks were to be enclosed and treated. The other three blocks were not, however, fenced in this year and so the only other figure available is a yield of 100,000 lbs. green grass from $4\frac{3}{4}$ acres of this block (or 21,053 lbs. per acre).

In addition in November 30,000 lbs. semi-dry grass was obtained from the whole 11 acres. The block was opened for grazing in December and 22 animals were allowed to graze. There was, however, very little sprouting of the cut grasses to give feed to the grazing animals.

In 1927 for the first time the whole of the land set aside for the experiment was fenced into five blocks. These are not all of the same size, due to a variety of causes. A brief note on each is given below.

Block I. $6\frac{3}{4}$ acres. The first enclosed (1923) and treated block, of which figures are given above.

Block II. 11 acres. Enclosed in 1926.

Block III. 11 acres. Enclosed in 1927.

Block IV. 11 acres. Enclosed in 1927, half of this block had to be cleared in 1927 of bushes and small trees.

Block V. 17 acres. The whole of this block had to be cleared in 1927 of bushes and small trees.

The scheme of treatment of these blocks was as follows:—

Blocks I and II. Cut grass for silage. Any grass remaining to be cut green and fed to cattle so that both blocks should have one complete cutting before the end of August.

Block III. Cut for hay in October.

Thereafter graze I, II and III in rotation during the rest of the year as long as each has any edible grass.

Block IV. Graze throughout the year.

Block V. Allow the grasses to produce seed and the seed to drop. Harvest the dry grass.

The actual carrying out of the scheme was as follows:—

Blocks I and II. Were not cut till September 17, 1927 on account of poor growth due to irregular and heavy rain. The amounts actually got were (in lbs.)—

	Block I	Block II
Green grass cut for silage	114,970	189,080
Green grass fed to cattle	*Nil.*	25,240
Totals .	114,970	214,320
Per acre .	19,161	16,486

Block III. On account of difficulty in getting labour this was not cut till October 25, cutting was, moreover, not done at one time for hay but day by day as the cattle required it as there was a shortage of grass that year. The total amount of semi-dry grass cut was 29,400 lbs. or 2,673 lbs. dry or semi-dry per acre. The block was open for grazing from December 13.

The blocks were then grazed by 22 cattle in the following rotation.

Block I. 30th October 1927 to 10th November 1927.
Block II. 10th November 1927 to 25th November 1927.
Block I. 25th November 1927 to 5th December 1927.
Block II. 5th December 1927 to 13th December 1927.
Block III. 13th December 1927 to 23rd December 1927.
Block I. 23rd December 1927 to 31st December 1927.
Block II. 31st December 1927 to 13th January 1928.
Block III. 14th January 1928 to 27th January 1928.
Block I. 28th January 1928 to 10th February 1928.
Block II. 11th February 1928 to 24th February 1928.
Block III. 25th February 1928 to 3rd March 1928.
Block I. 4th March 1928 to 12th March 1928.

From 12th March 1928 Blocks I and II are being grazed in a rotation of one week by 48 adult animals. From 12th April 1928, 56 animals (45 young animals and 11 adults) were kept in these blocks continuously.

Block IV. The rains made the land inaccessible during the early part of the monsoon but when possible 22 cattle were sent there from July 18. Continuous grazing was, however, possible only from September 10th and was carried out from that date. By April 1928 the grazing had been exhausted.

Block V. This block was cut in November and yielded 45,000 lbs. grass (or 2,647 lbs. dry grass per acre) and was open for grazing from December 18, 1927 for a herd of 54 animals young and old. In April 1928 as there was little feed left, the 54 animals were removed and 19 bull-calves let in to pick up what they could.

These figures give one some idea of the enormous grass-producing power of jungly land of moderate quality given the rainfall and temperatures of the Bombay coast. Generally speaking, one may expect 20,000 lbs. of green grass per acre, a certain amount of dry grass thereafter, but no grazing after cutting. To make the best of this large outturn of green grass the manufacture of silage is undoubtedly the best procedure, and of this fact the Bombay Gowrakshak Mandali became

gradually convinced. Starting tentatively with two silo pits they have now increased these to five. The details given below may be of interest.

	Silo Pits at Kandivlee				
	1	2	3	4	5
	Rs.	Rs.	Rs.	Rs.	Rs.
Cost to construct (pits are lined with brick and cement).	350	475	850	850	600
Dimensions in ft.—					
Diameter	16	18	19	19	17
Depth	10	11	14	15	13
Amount of grass in lbs. filled into each in the following years—					
1924	37,570	49,520	..	..	..
1925	61,500	80,000	..	..	..
1926	48,000	83,000	1,15,650	1,59,800	55,000
1927	60,700	74,965	90,620	77,765	*Nil.*

The ratio of finished silage to green grass is about 60 : 100. The silage is much liked by the cattle. The effect of feeding it is very manifest in the milk yield, which instead of going down in the hot weather is then maintained. Feeding of silage has also allowed the manager to reduce concentrates by 25 per cent. and so reduces the cost of production of milk. The condition of the cattle is excellent. The eating of silage seems to induce the animals to drink much more.

As to grazing in this area it is worth noting that it is undesirable to put the animals on the land when it is wet otherwise they puddle it and spoil the grass. Grazing, however, if confined to the periods when the land is not too soft is desirable both for the land and the cattle and if grazing is introduced into a rotation system in which cutting for silage is the main procedure then we should have an ideal system for this heavy rainfall area. Such areas if grazed according to this plan will carry 1·75 cattle per acre from September till the end of May.

The effect of fencing is already seen in the increased yields. The system of rotational grazing and cutting when in full swing should work the land to its fullest productive capacity.

V. Observations at Trombay.

The Bombay Gowrakshak Mandali decided to acquire and clear an additional area of jungle so as to have land for their dry stock. They therefore bought an area

of 125 acres on the side of a hill near Trombay (21 miles from Bombay) and in a rainfall similar to that of Bombay, *viz.*, 90 inches per annum between June and October.

This land when uncleared carried the following trees :—

Mangifera indica,
Phœnix sylvestris,
Borassus flabellifer,
Zizyphus jujuba,
Randia dumetorum,
Rhus mysorensis,
Carissa carandas,
Gymnosporia montana,
Lantana camara.

and in June 1927 (the trees having by that time been felled and most of them removed) carried a mass of green grass with *Scilla indica* and *Chlorophytum tuberosum* in flower amongst the grass.

This area was not the subject of experiment but only of observation, it being a large-scale ecological experiment, *i.e.*, a direct interference by man with the native vegetation.

In November 1927, *i.e.*, after one monsoon, the position was as follows :—In the uncleared area the grasses *Apluda varia* and *Anthistiria ciliata* occupied such spaces as they could find between the tree growth. In the cleared area the following grasses were present :—

Anthistiria imberbis
Iseilema laxum
Andropogon pertusus
Paspalum sanguinale
Ischæmum aristatum
Ischæmum rugosum
Apluda varia
Coix Lachryma-Jobi
Andropogon contortus (perennial)
Pollinia argentea
Arundinella Lawii
Setaria glauca

Anthistiria imberbis was dominant. Associated with it were *Pollinia argentea*, and *Andropogon annulatus, Arundinella Lawii, Andropogon contortus* (perennial). *Anthistiria ciliata* and *Apluda varia* were close societies, the last species being frequently mixed with *Tricholepis glaberrima*. *Ischæmum aristatum* and *Ischæmum rugosum* were characteristic of the lower areas and *Coix Lachryma-Jobi* was, as usual,

found in the lowest damp areas. *Celosia argentea* was prominent as a weed over the whole of the cleared area.

Other associated non-grass plants were :—

Impatiens balsamina
Geissopsis cristata
Flemingia tuberosa
Spermacoce stricta
Phaseolus mungo
Sesamum indicum
Trichodesma indica
Vicoa auriculata

We have thus in one year effective invasion by grassland (with associated weeds). The occurrence of the cultivated species *Phaseolus mungo* and *Sesamum indicum* as weeds is noticeable and the appearance of *Celosia argentea* in such quantities indicates the place usurped by ruderals in the first year of an invasion. It is likely that these ruderals will be ousted the following years.

We may, in parenthesis, remark that *Celosia argentea* seems to us to be a plant that is not only of very wide range of habitat, but which is also developing morphologically distinct local races in areas of different climatic and edaphic factors.

The grass was cut from September to November and there was no grazing in the season under report.

VI. Grasslands in the Southern Mahratta Country.

Bankapur.

This was referred to in our previous memoir, when we showed how between 1920 and 1925 the grass had improved, *Andropogon contortus* being largely replaced by other grasses.

Observations made in October 1927 showed almost no *Andropogon contortus* as the main area that carried this grass had been put under cultivation and there was no invasion of the grass elsewhere.

The main other changes noted were—

(1) The disappearance of *Argemone mexicana*. This is in accordance with what we know of the nature of this weed, which is a colonist of bare ground and cannot stand competition.

(2) The increase of *Lagasca mollis* on poor ground and heaps of masonry. This has more or less replaced *Argemona mexicana*. This also is in accordance with observations elsewhere.

(3) *Apluda varia* has increased in the area in which it was previously plentiful and has also invaded parts that contained *Anthistiria ciliata*.

(4) *Anthistiria ciliata* is appearing in an area previously dominated by *Ischæmum laxum*.

(5) *Achyranthes aspera* has increased under the trees. This is probably due to the cattle having to lie further and further from the tree as the weed vegetation increases, thus denuding still more ground for further invasion.

Tegur.

Work done after the publication of the last memoir consisted simply in experiments to decide the effect of ploughing on *Andropogon contortus*. In 1925 an acre of the grassland was ploughed and in 1926 another acre of grassland was ploughed. Neither received further treatment. These acres were not, however, in typical *Andropogon contortus* areas and the first one was definitely in an area where other grasses were dominant. The following observations are given for what they are worth :—

Acre ploughed in 1925 and then left untreated :—This area was more or less typical *Andropogon contortus* ground. It had been grazed to a certain extent in 1926 and then carried about 80 per cent. *Andropogon contortus* and 20 per cent. *Anthistiria ciliata*. In 1927 it carried about 50 per cent. *Andropogon contortus*, 20 per cent. *Ischæmum ciliare*, 17 per cent. *Anthistiria ciliata* and 3 per cent. *Ischæmum rugosum*.

Acre ploughed in 1926 :—This was not in a typical *Andropogon contortus* area and can be neglected.

Work done in 1927 :—To get the effect in a more typical area a long strip 350 ft. long and 25 ft. wide was ploughed right across an *Andropogon contortus* area. Within this at regular intervals three quadrats of 10 ft. side (100 sq. ft. each) were cleared by hand of all stumps of *Andropogon contortus*.

Observations in 1928 showed that in the three quadrats from which all *Andropogon contortus* had been removed the vegetation was sparse, only about one-tenth as thick as on the untouched grassland. Of this there was only 1 per cent. of *Andropogon contortus*, 96 per cent. being *Ischæmum rugosum* and 3 per cent. *Ischæmum ciliare*.

In the ploughed but not cleared portion there was a thicker stand of grass about one-third as thick as in the untouched land. It contained 16 per cent. of *Andropogon contortus*, 80 per cent. of *Ischæmum rugosum* and 4 per cent. of *Ischæmum ciliare*. In the surrounding unploughed area *Andropogon contortus* was present in the proportion of 60 per cent., *Ischæmum rugosum* 32 per cent., *Ischæmum ciliare* 8 per cent, and in one quadrat three plants of *Anthostiria ciliata*.

It is plain then that in the one year ploughing has greatly diminished the stand of *Andropogon contortus* and hand picking of the plant has reduced it still further. The other grasses of the neighbourhood have profited by this to come in and replace it. We shall see whether they can hold their own or not. The absence of *Anthistiria ciliata* is, we believe, to be explained by the fact that it is not a common grass in the neighbourhood.

Anthistiria ciliata was dominant on higher ground of good quality, with *Arthraxon ciliare* and *Setaria glauca* sub-dominant.

Belgaum.

The plots on the Vaccine Institute show little change. Of the reseeded plants only a few stumps of *Andropogon Monticola* and *Andropogon annulatus* survive. *Andropogon contortus* has come back but not to its original density. The area of better soil has also altered little.

It is probable that this lack of progress is due to the very poor nature of the soil in both plots which contains a large proportion of stones and a very small percentage of humus or of moisture.

VII. Notes on individual species of grasses.

Andropogon contortus.

Varieties. In the previous memoir we announced that there were at least two varieties of this grass in the areas that we had been studying, one small and annual and the other large and perennial. Since that time * two other workers in this Department have published a more detailed account of these varieties and we give herewith a summary of their observations and conclusions :—

† Hackel described several varieties of this species and of the two now under consideration the perennial appears to be his sub-variety *typicus* and the annual his sub-variety *hispidissimus*. In addition to the differences in roots, foliage and inflorescence mentioned in the previous memoir, there are marked differences in the colour of the essential parts of the flower. In the perennial the stigma is carmine and the anthers are vinaceous in colour, while in the annual the stigma is of blood-red and the anthers are sulphur-yellow.

There is little difference in the anatomy of the two varieties. We have confirmed the annual and perennial natures of these varieties by pot and plot cultures. The flowering season of the perennial is from October onwards and may last for four months from ratoon stems. The annual variety flowers from August to October. At the time of fruiting the awns of the perennial variety are twisted together and the fruits distributed in bunches, while the awns of the annual variety do not cling together nearly so much and the fruits tend to be distributed singly. (Pl. VI, fig. 1.) On the whole, the perennial variety is found in richer soil than the poor variety but this is not always the case and in certain areas of poor soil the perennial has been found invading if not too severely grazed.

* Patwardhan, G. B. ; and Hegde, G. R. Two Varieties of *Andropogon contortus*, Linn. *Jour. Ind. Bot. Soc.*, VI, 3 and 4 ; December, 1927 ; pp. 213-221.

† Hackel, Monogr. Androp. 585.

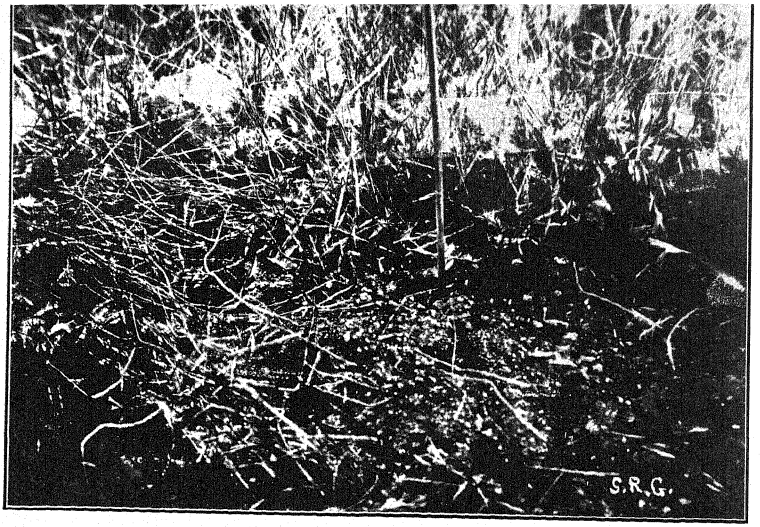
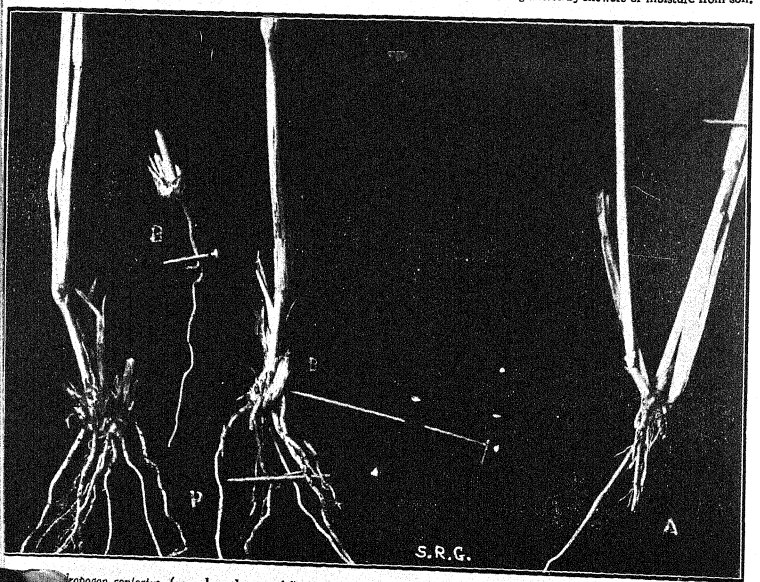


Fig. 1. *Andropogon contortus* (annual). Awns fall singly on the ground and penetrate after being wetted by showers or moisture from soil.



ropogon contortus (annual and perennial) showing dormant buds at the collar of *Andropogon*

The behaviour of the fruits of *Andropogon contortus* (annual) was studied in the following fashion. The fruits (with their awns) were allowed to fall from a height of two feet on to broken soil, on to smooth soil and on to soil containing perennial grass stumps. On the broken and the smooth soil the fruits landed and lay on their sides, while among the grass some of them were more or less upright. Experiments in pots with broken and smooth soil were then conducted, the soil being watered after the seeds had fallen. The awns began to twist and after 24 and 48 hours a number of fruits had actually penetrated and fixed themselves in the soil. A later column gives the germination after eleven days. See Table XI. It will be observed that those seeds which fell on broken ground had a better chance of penetration and hence also had a higher germination percentage. We have in the above experiment actually determined what has long been only a guess, namely, that the hygroscopic awns of this species do really cause the burying of the fruit in the soil.

The annual variety has a capacity for a much greater growth than it usually displays. This was very clear from an experiment made during the Bombay Presidency Agricultural Show held in Poona in 1926 when for demonstration purposes a plot of the annual and a plot of the perennial variety were grown side by side on good farm land. The perennial was planted by stumps and the annual by seeds. (Plate VI, fig. 2.) Each plot was 3 ft. by 6 ft. Yields of dry grass :—

Perennial	22 lbs.	Cut in December when dry.
Annual	35 lbs.	

In the previous memoir we have referred to the ploughing up and re-seeding of an area in the compound of Government House, Poona. This was done in 1916 and a later plot in 1919. The original vegetation of these plots had *Andropogon contortus* (annual) dominant with the perennial form scattered here and there. In 1922 the areas were opened to indiscriminate grazing by the Government House cattle and have been kept open since the whole year round and every year. In 1925 the *Andropogon contortus* has not come back. In 1928 the situation is practically the same. There are a very few patches of the perennial form, but over the area as a whole the species has no place. The species which are dominant are *Ischæmum laxum* and *Andropogon Monticola*. It is worth while mentioning this case specially, as it shows that, given certain conditions, *Andropogon contortus* can be eradicated by cultivations and replaced by re-seeding. The most essential of these conditions is that the number of cattle which graze on the area shall be moderate. This means adequate fencing.

VIII. A Line Survey of Grassland.

We have had occasion more than once to indicate the close connection between soil moisture and grass species. We have also described how in the heavy rainfall

on the coast at Kandivlee one finds a different grass flora from that found in dry areas. We are fortunate in being able to present a case where, within a comparatively short distance, there are very marked differences in the annual rainfall and associated therewith marked changes in grass species. This case has already been described in * another paper, and we give below nearly a brief summary.

Between Lonavla, situated between two eastern running spurs of the Western Ghats, with an average annual rainfall of 166·74 inches, and Sirur in the Bombay Deccan with an average annual rainfall of 20·96 inches, the distance in a straight line is about 60 miles and by road 79 miles. Following the road the grass vegetation was studied at 16 stations to a distance of a mile on either side of the road. The heavy rainfall station (Lonavla) is in a climate where the natural climax is monsoon forest, and this forest exists wherever cutting, or burning, or rice cultivation has not interfered with it.

On low-lying lands which would grow rice and where the soil is deep and clayey we found the dominant grasses to be *Andropogon odoratus*, *Pollinia argentea*, and *Ischæmum aristatum*. *Arundinella agrostoides* was fairly common and *Anthistiria ciliata* rare. On uncultivable shallow stony soil *Andropogon contortus* (perennial) was dominant, with *Anthistiria imberbis*, *Andropogon schœnanthus* and *Ischæmum laxum* sub-dominant. Where vegetation is just beginning to take hold on a mere powdering of soil above rock, the pioneer grass was *Rottbœllia divergens* associated with *Aneilema paniculatum*. In such places we also occasionally found *Ischæmum ciliare*.

At the station of low rainfall, Sirur, the natural climax is thorn-forest, and this is represented by *Acacia arabica* and *Capparis aphylla*, but these are much interfered with by browsing animals, especially goats, and hence the sub-climax stage, namely, xerophytic grassland, is everywhere visible outside the cultivated areas. The crops here are bajri (*Pennisetum typhoideum*) and jowar (*Andropogon sorghum*). On good soil the prevailing grasses are *Andropogon annulatus* and *Andropogon pertusus*. *Aristida species* are characteristic of poor shallow soil, and in fact the vegetation is like that of Kalas. At Talegaon with a 40-inch rainfall, on the border of the rice belt, where only coarse varieties of rice are grown in a few favoured fields, we find grassland at its best. The species are still of the same xerophytic type got near Poona but their growth is much greater. The real boundary between xerophytic and hygrophytic grassland takes place at Kamshet where the rainfall is about 44 inches annually, corresponding to the boundary between monsoon forest and thorn-forest.

IX. A Short Account of the Grass Trade at Talegaon.

The Military Grass Farms Department annually gets an enormous amount of dry grass from the neighbourhood of Talegaon which we have mentioned above as

* Burns, W.; and Kulkarni, L. B. A Line Survey of Grassland with Reference mainly to Rainfall. *Jour. Ind. Bot. Soc.*, Vol. 6, 3 and 4; December 1927; pp. 103-108.

being the place where xerophytic grassland is at its best. The area is in the Poona District and is about 72 square miles in extent, containing 19 villages. It is 2,000 ft. above sea level and is surrounded by the Sahyadri mountains. The land is uneven and eroded by nalas. The soil is the usual variable Deccan soil, varying from mere murum to deep rich black soil. The rainfall is 40 inches per annum, falling between June and September. As mentioned above, the area is still in the thorn-forest formation.

The above-mentioned 19 villages supply up to 6,000 tons of dry grass per annum of which the bulk is required by the army. There are also private contractors. Some of the grasslands are directly in charge of the army and are fenced, while privately-owned lands are not fenced but only watched.

The average composition of the grass harvested, as judged by inspection of several places, is as follows:—

	Per cent.
Anthistiria imberbis . . . . . } *A. ciliata*	50
Ischæmum laxum	30
Andropogon schœnanthus	10
Andropogon Monticola	5
Andropogon contortus (annual and perennial) . . . . . } *Arundinella agrostoides* and *Thelepogon elegans*	5

Grass cutting commences after the Dasara holidays and generally in the last week of October. It goes on until March with the result that most of the grass cut is hard, dry and woody. There is great difficulty in getting labour in October on account of the people being engaged in their own agricultural operations. Up to 1,500 labourers, many of them from outside places, are engaged daily in this work, generally on daily wages, the men getting 12 annas and the women 6 annas a day. The big coarse grasses are harvested first to make up weight quickly. The area is by no means exhausted and if a sudden call for additional grass is received later in the season it can usually be met. There is a lot of the grass which is never cut and either goes to waste or is consumed in one of the many grass fires that annually sweep across the area in the hot weather. The grass is baled and stacked at Talegaon Railway station. A stack is said to keep in good condition for three years. Grazing is in some places permitted in the early rains and again after the grass has been cut. There is little shade and the cattle graze during the dry season for an hour or two in the morning and then seek the banks of the river Indrayani which passes through the area. Trespassing by cattle on areas not opened to grazing is severely dealt with.

There is a belief that the yield per acre is getting lower and that the quality of the grass harvested from this area is deteriorating. It is very difficult to get accurate evidence on either point. As regards yield per acre it is nearly impossible

to calculate this figure as any area is cut to a varying extent in successive years. As to quality this can strictly speaking only be judged from the botanical composition of the bales and we have no data on this point previous to the present enquiry.

The area really deserves a special investigation to itself. The main facts that emerge are that the place is an eminently typical grassland formation, of the drier kind (considering Kandivlee as typical of the wetter kind), that its capacities are in no way completely exploited, and that its control on principles of ecology might well result in an improvement of both quality and quantity.

X. Conclusion.

There is at present in many countries an increasing interest in grasslands. In Britain the intensive production of grass is receiving attention from chemists, geneticists, practical farmers and fertiliser firms. In America the improvement of range lands continues to be the special study of many well-known workers in the Department of Agriculture and the Universities. In India there has been, on the whole, a lack of interest in this important subject. There have been various attempts to list the grasses of different provinces with notes, of more or less value, on their feeding qualities, but it is only recently that attention has been directed to two most important sides of grassland improvement, namely, how natural pasture actually behaves under different treatments and how animals do actually thrive when fed on different grasses and on grasses from different places or prepared in different ways. The last named type of work is in progress at the Imperial Institute of Animal Husbandry and Dairying in Bangalore, and the former type of work has been attempted by the present writers.

In the study of grass-farming, more, possibly, than in the study of any other type of agriculture, it is fatal to assume that what is good in one place is necessarily good in another. The problems of grassland improvement in India are markedly different from those in Britain, and though similar to the problems of range improvement in America still are not identical, due to differences in climatic, agricultural, economic and social conditions. Work in other countries may be a guide, but Indian problems have to be approached with an unbiassed mind.

Our work has been confined to one Presidency, but within that territory we have varied climatic conditions and consequently different kinds of grassland. Since our headquarters are in one of the drier areas, and also because the problems of grass production are more acute in such areas, we have naturally given a good deal of attention to xerophytic grassland. Of this we have distinguished three types so far as the Bombay Deccan is concerned, namely, that on hilly slopes, that on plains with poor shallow soil and that on plains with good soil. These differ in water content and in the species which they support. The good soil areas are naturally easy to improve, the hilly slopes gradually produce a good stand of perennial grasses, but the shallow areas take a long time to improve and it may be desir-

able (it certainly is possible, as we have shown experimentally) to accelerate their improvement by the artificial planting of stumps of perennial grasses. Shallow lands also suffer from burning, while the hilly and deep soil areas do not, especially if the burning is done early, *i.e.*, in February. No improvement can be initiated or maintained unless the number of animals to be grazed is limited and the number of these animals controlled. This means effective fencing.

Given fencing, the next thing is to decide on a scheme of management. In the case of good land that has been really badly over-grazed we recommend one year of complete rest to allow the vegetation to spring up and seed itself. Thereafter it is necessary to keep stock off the land during the early rains and to allow them on in limited numbers for the rest of the season. What these numbers shall be can only be determined by experiment, but our work goes to show that poor Deccan lands will carry one animal to 3 acres and good land in a heavy rainfall tract such as Kandivlee will *after the lush growth has been cut for silage* carry one animal to 0·6 acre. The figures for other grasslands probably come somewhere between these limits. Cutting for silage is an operation that should be practised wherever there is a rapid and vigorous growth of grass, and it should be done as early as possible so as to allow of the maximum recovery of the grass for grazing purposes. Cutting for hay is rarely done as it should be done, but in the few instances known to us when it has been properly done, many species including spear grass (perennial) produce an excellent hay. The cutting of dry grass at all stages of ripeness and toughness is the general method of harvesting, and the practical difficulties in altering this procedure are so great that we are unable at present to suggest any effective improvement. Manuring of grassland has not come within the scope of our experiments so far, and the universal practice of using dung as fuel automatically prevents the natural restitution to the soil of some of the material that the animal takes away. If one could popularise in India the practice of harrowing into grassland (even with so rough an instrument as a babul bush) the droppings of cattle, then considerable benefit would be derived. The use of artificial manure, which is proving so successful in Britain, may be of value on the better grasslands and is worth an experiment.

To sum up : contour bunding, fencing, limitation of the number of cattle, keeping these cattle off the land in the early monsoon, provision of easily accessible drinking water and rock salt, and tree planting for shade are the measures needful to improve poor grassland. To get the maximum outturn from good grassland there should be the liberal manufacture of silage early in the season, followed by rotational grazing by a limited number of animals, whose droppings should be harrowed into the soil and reinforced if necessary by artificial manure. For dry grass production cutting during or as soon after flowering as possible gives the best product. We recognise this must be, in many areas, a counsel of perfection, but it is worth aiming at. The increase of undesirable species or the reduction of undesirable species should be at once the object of a special expert investigation.

APPENDIX.

TABLE I.

**Soil and moisture conditions of the Kalas grass area during the years 1926 and 1927.*

Place	Year	Organic matter	Water content	Stones	Fine silt	Water penetration
Fenced area as a whole (check)	1926	8·00	9·08	29·24	14·75	7·05″
	1927	7·50	11·12	34·32	13·72	20·3″
Unfenced area	1926	7·53	7·32	29·93	12·99	5·29″
	1927	6·91	10·54	35·49	15·22	15·92″
Burnt area as a whole	1926	7·43	7·60	30·01	12·88	7·39″
	1927	7·48	10·88	39·58	13·92	22·90″
Hilly unburnt	1926	7·44	5·40	41·74	10·39	..
	1927	7·78	9·55	35·68	14·75	..
Hilly burnt	1926	5·28	6·15	38·88	6·79	..
	1927	8·62	8·46	48·33	11·49	..
Low unburnt	1926	10·35	14·83	23·83	19·18	..
	1927	8·62	14·99	32·65	20·11	..
Low burnt	1926	9·41	11·83	27·17	18·35	..
	1927	9·64	15·15	36·40	17·43	..
Shallow unburnt	1926	6·23	7·00	22·17	14·68	..
	1927	6·08	8·83	34·64	13·70	..
Shallow burnt	1926	5·26	4·83	24·00	13·50	..
	1927	5·24	9·03	34·00	12·85	..

* Figures in this and succeeding tables are percentages unless otherwise stated.

TABLE II.

Showing the organic matter and water contents at Kalas at three different times of the year during 1926 and 1927.

Area	Year	End of hot season		After first showers*		At the end of September	
		Organic matter	Total Moisture	Organic matter	Total Moisture	Organic matter	Total Moisture
Hilly enclosed	1926	7·92	2·00	7·81	3·50	6·62	10·71
	1927	8·72	10·40	7·12	12·25	7·50	6·00
Hilly unenclosed	1926	6·60	2·00	7·44	5·50	7·34	8·89
	1927	8·00	6·40	7·16	11·25	7·16	5·50
Hilly burnt	1926	7·62	2·50	7·71	5·00	7·52	10·95
	1927	8·16	7·88	7·48	11·00	7·06	6·50
Low enclosed	1926	9·54	5·50	10·16	12·50	11·34	26·50
	1927	10·74	13·72	9·22	18·25	5·90	13·00
Low unenclosed	1926	7·76	5·00	8·66	10·00	7·06	21·50
	1927	7·44	12·88	8·04	13·75	4·54	18·00
Low burnt	1926	9·80	5·00	9·31	11·00	9·12	19·50
	1927	10·40	11·20	10·12	18·25	8·40	16·00
Shallow enclosed	1926	7·01	1·00	6·62	10·00	5·06	10·00
	1927	5·50	8·40	6·40	12·60	6·34	5·50
Shallow unenclosed	1926	7·16	1·00	7·48	6·00	8·38	5·00
	1927	5·40	6·80	7·20	8·52	7·22	7·00
Shallow burnt	1926	5·30	1·00	5·29	7·00	5·08	6·50
	1927	5·02	6·60	6·20	14·06	4·50	6·50

NOTE.—Samples taken from total depth of soil occupied by the grass roots, i.e., in shallow and hilly areas up to about 6 inches and in low areas up to about 18 inches.

* In 1926 readings were taken after 1·11 inches rain.
In 1927 readings were taken after 3·7 inches rain.

TABLE III.

Grass yield (in lbs.) from different strips at Kalas. Cut in November.

Strips	1924		1925		1926		1927	
	Actual	Per acre	Actual	Per acre	Actual	Per acre	Actual	Per acre
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cut	355	557	434	682	969	1,513	1,207	1,900
Feb. burnt	..	..	..	..	1,206	1,917	1,229	1,977
May burnt	..	..	..	..	797	1,388	845	1,493

TABLE IV.

Showing the average number of spikelets (average of 5 plants in each case) produced per plant from different strips in the Kalas grass area 1927.

ANDROPOGON MONTICOLA

Hilly		Low		Shallow	
Check	1,940	Check	1,358	Check	803
Cut	2,186	Cut	1,779	Cut	1,371
Burnt	1,705	Burnt	2,377	Burnt	3,327

ISCHÆMUM LAXUM

Hilly		Low	Shallow	
Check	2,821		Check	1,388
Cut	2,155	No stumps	Cut	3,541
Burnt	5,818		Burnt	4,807

TABLE V.

Average number of spikelets produced per plant.

	Hilly	Low	Shallow	Outside
Andropogon Monticola	724	670	795	287
Ischæmum laxum	1,260	No stumps	1,192	475

TABLE VI.

Plant population and area (in sq. cm.) occupied by stumps from the temporary quadrats (sq. metre) recorded during the last week of September at Kalas.

Locality	Plant population		Area in sq. cm.	
	1926	1927	1926	1927
Hilly check	1,281	2,848	12·57	25·53
„ cut	1,400	2,056	..	..
„ Feb. burnt	1,101	2,698	..	8·83
„ May burnt	784	1,439	..	..
„ outside	631	1,765	..	..
Low check	377	344	620·91	872·62
„ cut	587	711	626·95	1019·37
„ Feb. burnt	166	88	1347·82	2027·61
„ May burnt	429	928	566·74	851·18
„ outside	1,606	1,163	144·71	233·23
Shallow check	681	3,056	..	0·20
„ cut	884	2,601	..	..
„ Feb. burnt	822	1,323	4·05	7·07
„ May burnt	643	1,407	..	..
„ outside	1,064	2,497	18·7	22·23

TABLE VII.

Showing the grass and non-grass population from temporary metre quadrats in different strips at Kalas.

HILLY AREA

Year	CHECK		CUT		FEB. BURNT		MAY BURNT		OUTSIDE THE FENCE	
	Grass	Non-grass	Grass	Non-grass	Grass	Non-grass	Grass	Non-grass	Grass	Non-grass
1925	421	956	1,180	1,504	1,939	1,079	2,399	535	743	119
1927	543	2,305	1,794	262	2,167	531	1,133	306	1,025	740
SHALLOW AREA										
1925	1,002	256	1,411	1,221	1,910	606	1,850	191	987	393
1927	2,796	260	2,021	580	1,153	172	1,219	188	1,693	804

TABLE VIII.

Change in total number of plants per quadrat.

	1920	1921	*1922	1923	1924	1925	1926	1927
Group I.								
Original . . .	318	771	..	1,011	1,049	862	313	1,139
Scraped . . .	..	127	..	810	722	925	434	841
Burned . . .	..	547	..	1,547	1,139	1,105	553	1,769
Group II.								
Original . . .	177	1,360	..	..	1,939	406	594	1,058
Scraped . . .	..	574	..	..	809	486	563	1,275
Burned . . .	..	472	..	..	1,728	330	785	1,824
Group III.								
Original . . .	22	593	..	534	497	478	325	977
Group IV.								
Original . . .	490	691	..	901	821	1,280	675	2,491
Scraped . . .	..	279	..	1,621	553	1,226	484	1,885
Burned . . .	..	659	..	1,142	826	735	521	2,284
Group V.								
Original . . .	686	892	..	1,425	1,784	2,109	519	1,708
Scraped . . .	..	406	..	1,508	1,266	1,864	555	2,154
Burned . . .	..	659	..	1,744	1,972	1,838	496	2,057
Group VI.								
Original . . .	401	397	..	..	656	304	204	167
Scraped . . .	..	218	..	..	590	337	339	295

* Records faulty.

TABLE IX.

Change in number of species per quadrat.

——	1920	1921	*1922	1923	1924	1925	1926	1927
Group I.								
Original . . .	7	7	..	21	25	11	11	14
Scraped . . .	..	11	..	33	34	19	25	25
Burned . . .	..	9	..	23	32	15	15	16
Group II.								
Original . . .	11	9	..	..	19	14	17	21
Scraped . . .	..	19	..	..	21	21	19	24
Burned . . .	..	12	..	..	23	12	15	19
Group III.								
Original . . .	3	13	..	9	9	6	5	11
Group IV.								
Original . . .	23	19	..	17	31	14	18	23
Scraped . . .	..	19	..	12	22	9	13	13
Burned . .	..	10	..	16	32	14	17	13
Group V.								
Original . . .	17	17	..	21	22	15	10	14
Scraped . . .	..	20	..	22	25	13	15	12
Burned . . .	..	12	..	24	24	17	11	16
Group VI.								
Original . . .	11	13	..	..	16	10	12	10
Scraped . . .	..	9	..	..	19	5	10	14

* Records faulty.

TABLE X.

Showing the classification of sub-climax grass lands into three classes.

Place	*Rainfall	Date of taking samples	STONY SOILS			GOOD DEEP SOILS			FLAT SHALLOW SOILS		
			Depth of soil inches	Moisture %	Vegetation	Depth of soil inches	Moisture %	Vegetation	Depth of soil inches	Moisture %	Vegetation
Govt. House, Poona	..	19-1-27	..	..	....	8·50	11·46	*Andropogon contortus* (perennial) dominant, *Andropogon foveolatus*, *Iseilema anthephoroides*, *Andropogon pumilus*.	3·70	4·88	*Andropogon contortus* (a.) dominant, *Andropogon foveolatus*, *Andropogon contortus* (per.), *Andropogon pumilus*, *Heylandia latebrosa*, *Indigofera linifolia* appearing.
Bhamburda	..	25-1-27	..	..	....	36·00	8·70	*Iseilema anthephoroides*, *Andropogon Monticola* dominant, *Ischaemum laxum*.	10·00	7·80	*Andropogon contortus* (a.) dominant, *Andropogon Monticola*, *Andropogon foveolatus* and *Aristida varia* appearing.
Bhamburda	..	9-10-26	..	..	....	36·00	12·56	*Andropogon Monticola*, *Andropogon foveolatus* dominant, *Andropogon annulatus*, *Iseilema anthephoroides* scattered.	..	..	
Jalgaon	..	20-12-26	5·8	6·10	*Andropogon Monticola* dominant, *Ischaemum laxum*.	13·00	11·20	*Iseilema anthephoroides* dominant, *Ischaemum pilosum*.	..	..	
Padmavati	34·54"	27-1-27	7	6·00	*Andropogon pertusus* dominant, *Andropogon contortus* (per.) and *Tripogon Jacquemontii*.	16·00	9·78	*Andropogon annulatus* dominant, *Andropogon pumilus* and *Iseilema anthephoroides*.	7·00	4·75	*Andropogon contortus* (a.) dominant, *Andropogon Monticola*, *Andropogon contortus* (per.) and *Andropogon foveolatus* appearing.

Kalas	21·11″	21-1-27	3·5	4·29	*Ischæmum laxum*, *Andropogon Monticola* dominant.	24·00	9·40	*Andropogon annulatus* dominant, *Iseilema laxum*.	6·00	4·01	*Andropogon contortus* (a.), *Aristida funiculata* dominant, *Ischæmum laxum* appearing.
Sirur	8·00″	20-12-26	3·0	14·02	*Ischæmum laxum*	42·00	17·40	*Andropogon annulatus* dominant, *Andropogon pertusus*.	..	..	
Shikrapur	..	20-12-26	..	..	..	13·00	14·04	*Andropogon annulatus* dominant, *Andropogon pertusus*.	..	..	
Kondapur	..	20-12-26	3·66	4·58	*Andropogon contortus* (per.) dominant, *Andropogon Monticola*, *Ischæmum laxum*.	..	..	....	..	..	
Koregaon	..	20-12-26	3·00	15·50	*Ischæmum, æxum*	..	..	....	..	..	
Koregaon	..	20-12-26	4·5	6·60	*Andropogon contortus* (per).	..	..	....	..	..	
Lonikand	..	20-12-26	..	..	....	13·50	16·04	*Pennisetum Alopecuros*.	..	..	
Wagholi	..	20-12-26	..	..	....	9·00	10·60	*Andropogon pumilus* dominant.	..	..	
Dapodi	..	20-12-26	..	..	....	12·00	15·90	*Andropogon annulatus* dominant, *Andropogon pertusus*.	2·00	2·70	*Andropogon contortus* (a.), *Aristida funiculata* dominant.
Chinchwad	..	20-12-26	..	..	....	12·00	16·30	Ditto	3·50	3·22	Ditto.
Shelarwadi	..	20-12-26	..	..	....	12·00	8·45	*Andropogon annulatus* dominant, *Andropogon contortus* (per.).	4·00	5·40	Ditto.
Vadgaon	43·78″	20-12-26	1·50	4·50	*Andropogon contortus* (per.) dominant, *Andropogon schœnanthus* and *Anthistiria ciliata*.	24·00	33·00	*Pennisetum Alopecuros*.	..	..	
Kamshet	85·00″	20-12-26	3·0	5·12	Ditto	27·00	18·00	*Andropogon annulatus* dominant, *Anthistiria ciliata*, *Pollinia argentea*.	..	..	

* For year, at date of sampling.

TABLE X—*contd.*

Showing the classification of sub-climax grasslands into three classes—contd.

Place	Rainfall	Date of taking samples	STONY SOILS			GOOD DEEP SOILS			FLAT SHALLOW SOILS		
			Depth of soil inches	Moisture %	Vegetation	Depth of soil inches	Moisture %	Vegetation	Depth of soil inches	Moisture %	Vegetation
Malavli	1·49″	20-12-26	4·0	3·67	*Andropogon contortus* (per.).	16·00	9·30	*Andropogon odoratus*, *Pollinia argentea* dominant.	..	..	
Lonavla	..	20-12-26	7·00	6·32	*Andropogon contortus* (per.) dominant, *Anthistiria imberbis*.	60·00	13·60	*Andropogon odoratus* dominant, *Pollinia argentea*, *Ischæmum aristatum*.	..	..	

Names by which some of the grasses mentioned in Table X are known in the Deccan.

Name of grass.	Vernacular name (Marathi).
Andropogon contortus	Kusal.
,, pumilus	Gondval.
,, odoratus	Vedi gavat.
,, Monticola	Dongri gavat.
,, annulatus	Marvel.
,, foveolatus	Kadu marvel.
,, pertusus	Ghanya marvel.
Ischæmum laxum	Sheda.
,, pilosum	Kunda.
,, aristatum	Ber.
Iseilema laxum	Moshi.
,, anthephoroides	Moshi.
Aristida funiculatá	Lahan kusal.
Anthistiria ciliata	Phul gavat.
Pennisetum Alopecuros	Mole.

TABLE XI.

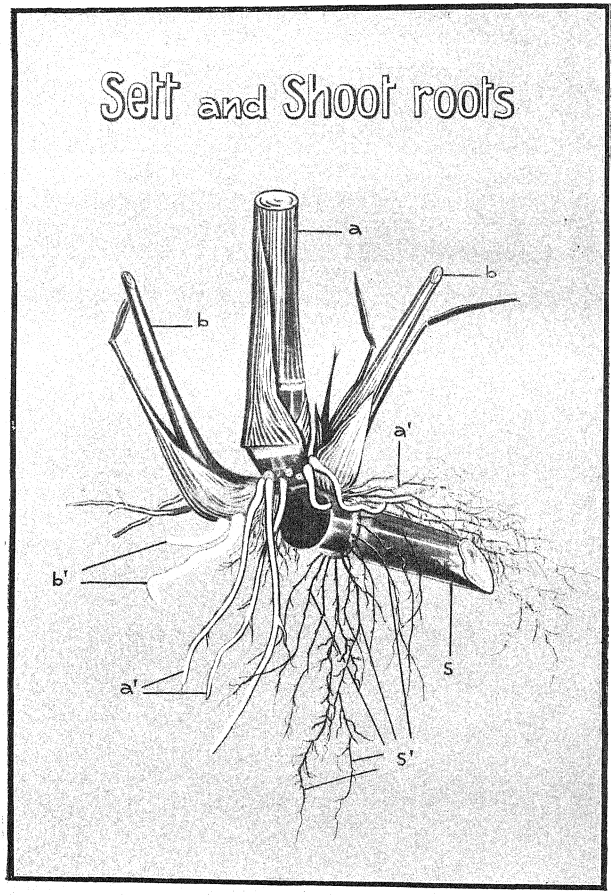
Showing the penetration and germination of Andropogon contortus (annual) seeds.

No. and kind of pot	No. of fruits	Date of dropping fruits	PENETRATION			GERMINATION					Per cent
			After 24 hours	After 48 hours	Per cent.	15 March 1928	16 March 1928	17 March 1928	19 March 1928	23 March 1928	
Pot 1 (broken soil)	50	12-3-28	23	27	54	4	12	16	18	19	38
Pot 2 (broken soil)	50	12-3-28	20	26	52	4	9	14	15	15	30
Pot 1 (compact soil)	50	12-3-28	14	16	32	0	0	1	3	7	14
Pot 2 (compact soil)	50	12-3-28	4	12	24	1	4	4	5	11	22

MGIPC—M—III-1-75—4-3-29—650.

CONTENTS

LIST OF ILLUSTRATIONS.



S. The original planted sett.
S^1. *Sett* roots (formed from the sett).
a. The first shoot developed from the sett.
a^1. *Shoot* roots developed from *a*.
b. Other shoots developed from *a*.
b^1. *Shoot* roots developed from *b*.

STUDIES OF SUGARCANE ROOTS AT DIFFERENT STAGES OF GROWTH.

BY

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AND

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(Received for publication on 3rd July 1928.)

I. Early (germination) stages—period of Sett roots.

(1) *Sett roots and their formation.*

In ordinary cultivation the sugarcane is grown from cuttings or '*setts*'* as they are also called. To start germination these cuttings are planted in soil already containing a sufficiency of moisture to germinate the buds; or, where the soil moisture is deficient, periodic and suitable irrigations are given to maintain the moisture in the soil. When the sett comes into contact with the moisture in the soil, it absorbs the moisture and certain changes take place in it. Usually, one of the first activities in the planted sett is the development of roots from the translucent dots or 'root eyes' found at the base of every cane joint. These translucent dots are really the incipient or resting root tips and are often the first to be called into activity during germination. It is proposed in this paper to call these roots '*sett*' roots because of their origin from setts and in contrast with '*shoot*' roots to be described later.

(2) *Number of root eyes developing sett roots.*

Sugarcane varieties show interesting differences in the number and length of sett roots that are developed during the first stages of germination (Table I and Pl. I). The number of sett roots formed is large in the case of the tropical canes as compared with that in the Indian canes. The now popular Coimbatore seedlings mostly resemble the Indian canes apparently because of their parentage, while the P. O. J. seedlings thus far studied tend more towards the tropical types. *Saccharum spontaneum* is rather different from *Saccharum arundinaceum* in this respect as seen from Plate I which was prepared from photographs taken sixteen days after planting.

* In publications from Madras where this term is most commonly used, it is sometimes spelt '*set*' and at other times 'sett'. The latter spelling has been adopted to keep it distinct from the word with one 't'.

It needs to be mentioned here that the Indian canes show differences according to the group to which they belong. The canes belonging to the Pansahi group develop the fewest number of sett roots and a more detailed study of the rooting phenomena might throw some light on the phylogenetic relationships of the different groups of canes. The Java cane *Kassoer* develops a small number of sett roots suggesting its derivation from *Sacch. spontaneum*.

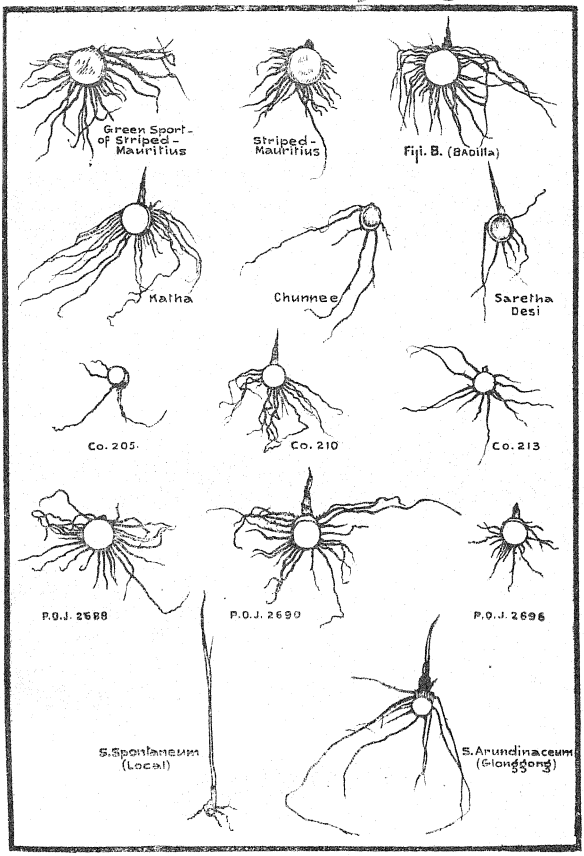
In certain cane seedlings derived from *Sacch. spontaneum* as also in *Sacch. spontaneum* itself all the root eyes do not take part in the first formation of sett roots (Pl. I, figs. of *Sacch. spontaneum* and Co. 205). Some of the root eyes continue dormant and develop roots later on, should the need arise. This would appear to be a definite and valuable provision against possible adverse conditions during the early stages of growth. It is as if the plant were reluctant 'to place all its eggs in one basket' in the matter of the formation of the first batch of sett roots.

TABLE I.

Number of sett roots developed during germination.

Name of variety	Group		Number of sett roots developed ten days after sowing
			(Average of 20 countings)
Striped Mauritius	Tropical canes	Indian canes	56·2
Green Sport of Striped Mauritius			50·3
Badila (Fiji B)			34·9
B. 254			30·6
B. 3412			13·9
Kaludai Boothan			42·8
Katha	Saretha group		31·9
Chunnee			6·8
Sarotha desi			10·7
Ketari	Pansahi group.		1·5
Chinia			2·8
Uba			1·6
Sewari	Nargori group		6·6
Nargori			10·8
Manga			15·5

Germination: Early stages.



Sett root development sixteen days from sowing (from photographs). Co. 205 is a hybrid with *Sacch. spontaneum*. Differences exist between varieties in the number as well as in the length of sett roots. **There is no correlation between sett root development and sprouting of buds.**

Note.—Fiji B is the Indian name for Badila.

TABLE I—*contd.*

Number of sett roots developed during germination—contd.

Name of variety	Group	Number of sett roots developed ten days after sowing
		(Average of 20 countings)
Co. 205	Coimbatore seedlings	3·2
Co. 210		21·2
Co. 213		8·9
Co. 281		7·4
P. O. J. 1547	P. O. J. Seedlings	21·5
P. O. J. 2631		23·4
P. O. J. 2688		25·6
P. O. J. 2690		28·5
P. O. J. 2696		19·1
Saccharum spontaneum	Wild Saccharums	2·3
Sacch. arundinaceum ; (Glonggong of Java)		7·7

(3) *Bud sprouting not correlated with sett root development.*

From general considerations it should be an advantage to the young plant to start with an early development of a fair number of sett roots. Such a development (of sett roots) would enable the plant to obtain its nutrition from the soil earlier than in the case of varieties which develop these roots at a later stage. In the latter case the developing shoot will have to depend on the food stored in the sett during its earlier stages of development and till the sett roots are formed and establish connection with the soil.

The varieties belonging to the Pansahi group of Indian canes develop sett roots late. In certain of them the bud attains a fair amount of growth before the setts begin to produce roots. There is thus no direct relation between the very first stages of bursting and shooting of the buds and the development of roots from the sett. The words 'bursting' and 'shooting' are used deliberately in contrast to a proper and efficient germination, for which sett roots would appear to be essential.

(4) *Sett roots essential for proper bud germination.*

That, sett roots are essential, for a proper germination and development of the bud into a shoot has been shown in a previous publication.[1] It was there indicated

[1] Venkatraman, T. S. Studies in Sugarcane Germination. *Agri. Jour. India*, Vol. XXI, pt. 2, p. 101.

that the bud, however carefully sown and tended, would not germinate properly and develop into a functioning shoot, unless the bud had attached to it at least one root eye with the possibility of developing at least one sett root. It therefore follows that, whereas for the swelling, the bursting and early stages of shooting, the presence of sett roots is not apparently absolutely necessary, their presence is essential for the proper germination and growth of the bud.

(5) *Quality of irrigation water and its effect on sett root development.*

It is well known that the cane is particularly susceptible to the quality of irrigation water[1]—though certain varieties appear to be capable of taking from the soil large quantities of saline matter. Saline waters exert a harmful effect on germination by retarding the formation and development of sett roots (Pl. II). Care should therefore be taken to irrigate the canes with water of good quality during the earliest stages of germination. The check in growth resulting from irrigation with saline water during the early stages of germination is well seen from Table II.

TABLE II.

Quality of irrigation water and its effect on sett root development. (Weight of shoots and roots: Plants 20 days old.)

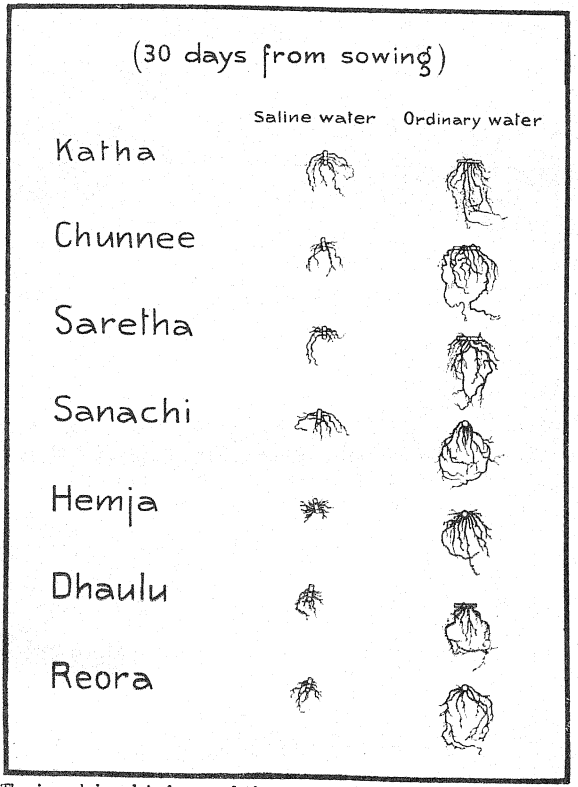
Variety	Irrigated with ordinary water			Irrigated with saline water		
	No. of plants examined	Average dry weight in grammes		No. of plants examined	Average dry weight in grammes	
		Shoot portion	Root portion		Shoot portion	Root portion
Katha . . .	5	0·470	0·160	2	0·210	0·075
Chunnee . .	6	0·445	0·120	4	0·205	0·020
Saretha . .	6	0·265	0·087	5	0·191	0·036
Dhaulu . . .	6	0·353	0·153	4	0·128	0·045
Hemja . . .	5	0·300	0·070	5	0·214	0·034
Rheora . . .	6	0·150	0·053	All plants unhealthy.		
Sanachi . .	6	0·421	0·078	5	0·176	0·012

The 'ordinary' water in the above experiments contained 78·0 total solids in 100,000 parts. The 'saline' water contained a little over 500 parts. The salts were chiefly sodium chloride and sodium carbonate.

[1] Krishnamurthi Rao, K. Irrigation Water for Sugarcane Cultivation. *Year Book, Madras Dept. Agri.*, 1920-21, p. 97.

Irrigation water & sett roots development.

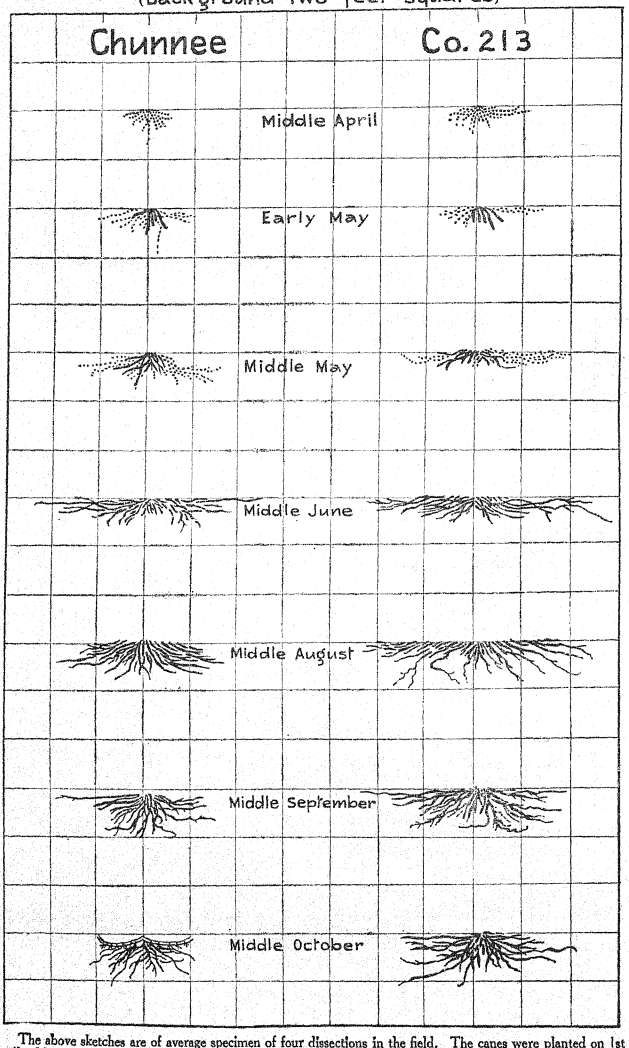
(30 days from sowing)



There is a marked retardation in *sett* root development when planted *setts* are irrigated with saline water. **Irrigation with saline water should therefore be avoided.**

Periodic Root Dissections.

(Background two feet squares)



The above sketches are of average specimen of four dissections in the field. The canes were planted on 1st April. Note the gradual death of *sett* roots (dotted lines), as the plants grow. Owing to the constant production of new roots, the root system of the cane varies from time to time. **A detailed knowledge of root systems at different stages would be a valuable guide to the conducting of manurial and cultural operations with the maximum advantage to the crop.**

II. Later stages in growth—shoot roots and their development.

(1) *Formation of shoot roots.*

Although, as already mentioned, sett roots are apparently essential for germination and the early stages in the development of the bud into a shoot, these roots generally die after a time (Pl. III and Table III). On account of their temporary nature, the corresponding roots in cereals have been styled "*temporary roots*" by other authors.[1] Latter on, the growing plant is dependent for its nutrition on other roots which develop later from the shoots, be they the first formed 'mother' shoots or other shoots which are subsequently developed from this 'mother' shoot. It is proposed to call these '*shoot*' roots, because of their origin from *shoots* and not from *setts*. These shoot roots differ in certain respects from the first formed sett roots; and certain of these differences will be briefly dealt with in a subsequent section of this paper. The shoot roots of the cane plant, in a way, correspond to the '*nodal*' roots of barley and the sett roots to the '*seminal*'.[2]

The period during which sett roots function differs in the different varieties. The sett roots of *Sacch. spontaneum* function the longest and certain of the hybrids with *Sacch. spontaneum*—like Co. 205[3]—have shown this character.

Table III.

Relative weights of sett and shoot roots at different stages of growth.

(Average of 5 plants.)

Name of variety	Age of plant	Dry weight in grammes	
		Sett roots	Shoot roots
	Days		
Katha	36	0·3	2·9
	58	0·2	10·2
	78	0·1	18·4
	104	0·1	31·3
Saretha	37	0·8	2·9
	58	0·7	11·7
	81	0·4	19·6
	104	0·1	27·2
Hemja	39	0·4	2·2
	60	0·5	7·5
	81	0·4	9·7
	105	0·2	19·4
E. K. 2	40	0·9	1·2
	64	0·5	3·7
	83	0·5	7·6
	110	0·3	17·3

[1] Wiggans, R. G. *Jour. American Soc., Agronomy*; Vol. VIII, 1916, p. 31.
[2] Jackson, V. G. *Ann. Bot.*, Vol. XXXVI, 1922, p. 21.
[3] Venkatraman, T. S., and Vittal Rao, U. Coimbatore Seedling Canes. *Agri. Jour. India*, Vol. XXIII, pt. 1, p. 28.

(2) *Growth of plant dependent on shoot root development.*

The shoot roots play an important *role* in the further growth and development of the cane plant and constitute the sole root system of the plant after the death of the sett roots. If under experiment a growing cane plant is continuously deprived of its shoot roots as they develop and made to depend entirely on the first formed sett roots, its vigour suffers markedly in comparison with the control (Pl. VII, Figs. 6 to 9).

In one experiment, where ten plants of Co. 213 were grown on sett roots alone and another ten plants in the normal manner—*i.e.* on sett and shoot roots—it was found that the sett root plants did not arrow when the season came round. The control plants arrowed freely. These plants were five months old when the arrowing season arrived.

The vigour of growth of shoot roots differs according to the variety, being generally greater in the Indian canes as compared with the tropical kinds. Certain of the Coimbatore seedlings take more after the Indian canes. In the varieties studied, a positive correlation has been definitely indicated between shoot-root vigour and the vegetative vigour of the plants. (Pl. IV.)

(3) *Mode of branching (tillering) in the sugarcane.*

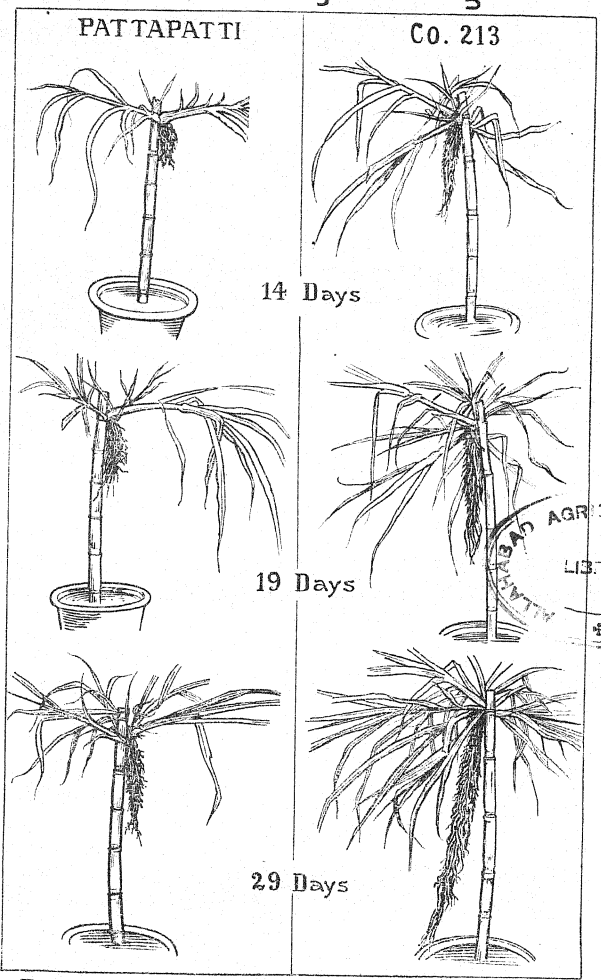
To understand clearly the root system of the adult plant, consisting almost entirely of shoot roots, it is necessary to notice very briefly here the process of branching or tillering as it takes place in the sugarcane. This subject has been dealt with very elaborately by Dr. Barber in one of his publications.[1]

What is known ordinarily as the germination of a planted sett is really the germination and sprouting of the bud or buds contained in the sett. These buds—the original buds on the sett—soon develop into shoots, an incipient stem or cane being formed in each at a very early stage in the development of the shoot. These incipient canes can be seen by taking a vertical section of the shoots, when they will be found to possess both incipient root eyes as well as incipient buds. These incipient root eyes soon give rise to roots—the first 'shoot' roots of the plant and the buds develop into 'daughter' shoots. The 'daughter' shoots in their turn develop other shoots—the 'grand-daughter' shoots—and the process continues till a fairly late stage in the life of the plant. This results in the formation of what is ordinarily known as the 'Sugarcane clump,' such a clump being formed of (1) the mother shoot, (2) a certain number of 'daughter' shoots, (3) a greater number of 'grand-daughter' shoots and so on. Each of the shoots in the clump possesses incipient root eyes containing root primordia and therefore capable of developing into roots under favourable conditions of growth.

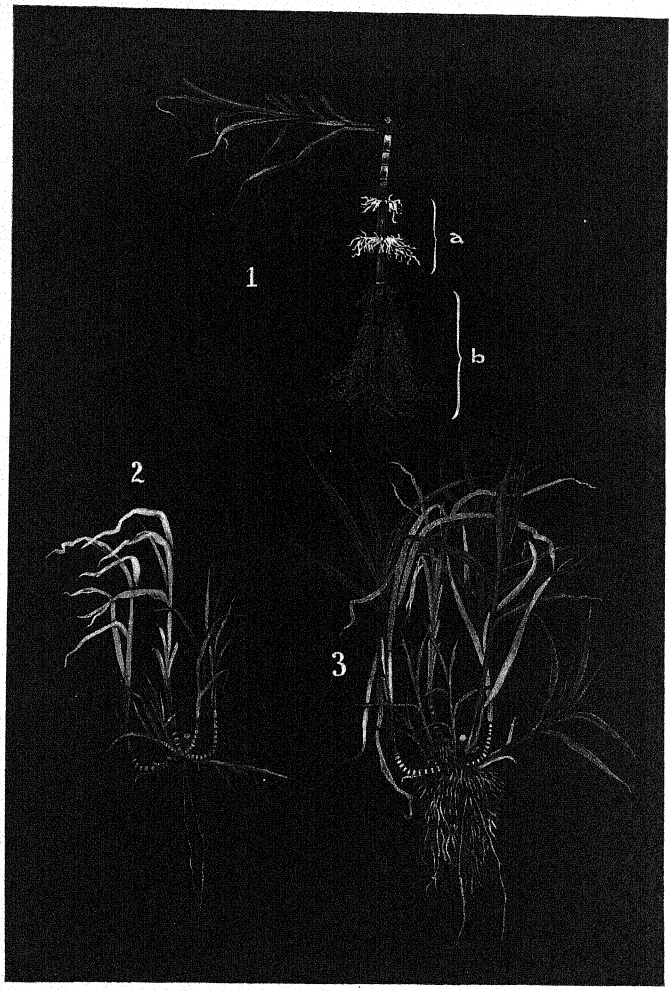
[1] Barber, C. A. Tillering or Underground Branching; *Mem. Dept. Agri. India, Bot. Ser.*, Vol. X, No. 2.

the maximum advantage to

Shoot Roots — Vigour of growth



These pictures have been drawn to the same scale from photographs. The shoot roots of Co. 213 when 29 days old measured 26 inches in length. The pictures show a positive correlation between shoot-root vigour and the vegetative vigour of the plants. **It is therefore desirable to encourage quick and vigorous development of shoot roots.** Earthing up the crop at the right time is one method of doing this.


a
b
1
2
3

III. The root system of the adult plant.

We have just seen that the adult plant consists of a mass of shoots of different orders, each of the shoots possessing incipient root eyes capable of developing into roots under favourable conditions of growth. In ordinary cultivation the basal nodes of most of the shoots are either inside the soil or very close to it. The periodic earthings which are given to the crop bring these basal portions and hence the incipient root eyes under the soil and thus create favourable conditions for the development of fresh roots from the root eyes. As the result of this, fresh roots are more or less continuously thrown out by the clump into the soil.

(1) *Continuous development of new roots.*

Like the sett roots the shoot roots also die after a time, their place being taken by other fresh roots, developed from other nodes in the same shoot or from other daughter or grand daughter shoots. This explains the rather considera'le changes in the habit and plan of root systems in the periodic root dissections (Pl. III). If the soil were transparent and one could watch the continuous root activities of the sugarcane clump, one would notice an almost continuous production of fresh roots, the older roots dying out and getting incorporated with the soil. The authors realized this aspect of the root activities of the cane plant for the first time when they grew canes in water culture and the root development thus became clear for continuous observation.[1] This was afterwards fully borne out by periodic root dissections in the field.

Whenever there is a chance—and from the mode of branching already described there are plenty of chances under ordinary crop conditions—the cane plant prefers to develop fresh roots for obtaining nourishment rather than depend upon the older ones. By a clever arrangement, originally designed by the junior author,[2] it has been possible to grow canes away from the soil, on a definite number of roots and without any possibility of other new roots developing. Under such conditions the plants gradually lost vigour and died out. When, however, a plant thus starved for fresh roots was given opportunities to develop them, the plant at once grew on in a remarkable manner (Pl. V, Figs. 2 & 3). The importance of a continuous development of fresh roots in the life of the sugarcane plant is thus obvious.

(2) *Advantages resulting from the continuous production of fresh roots.*

This constant and almost continuous production of fresh roots enables the cane plant to adjust its root system to the prevailing environmental conditions with a considerable degree of nicety. When periodic dissections are made of the

[1] Venkatraman, T. S., and Thomas, R. Simple contrivances for studying root development in Agricultural crops. *Agri. Jour. India*, Vol. XIX, pt. 5, p. 509.

[2] Thomas, R. A Method of studying the roots of Sugarcane. *Agri. Jour. India*, Vol. XXII, pt. 2, p. 138.

same plant or variety, it is found that they greatly differ from one another according to the conditions of growth obtaining at each period of dissection. This is well illustrated by the dissections figured in Pl. III. It is interesting to see how the root system which was comparatively shallow during middle June—the period of a comparatively high water table in the particular field at Coimbatore—changes into a much deeper root system during September—October as the water table drops. In the case of a plant with a more permanent root system this adjustment to an altered set of environmental conditions would be made by the development of a set of lateral roots growing towards places of available moisture. In the cane, however, the new roots which are constantly formed are able to direct themselves almost immediately towards points of vantage in the soil. A realization of this phenomenon in the sugarcane has enabled the authors to understand certain otherwise puzzling features in the root system of the same plant or variety at different periods.

(3) *The adult root system.*

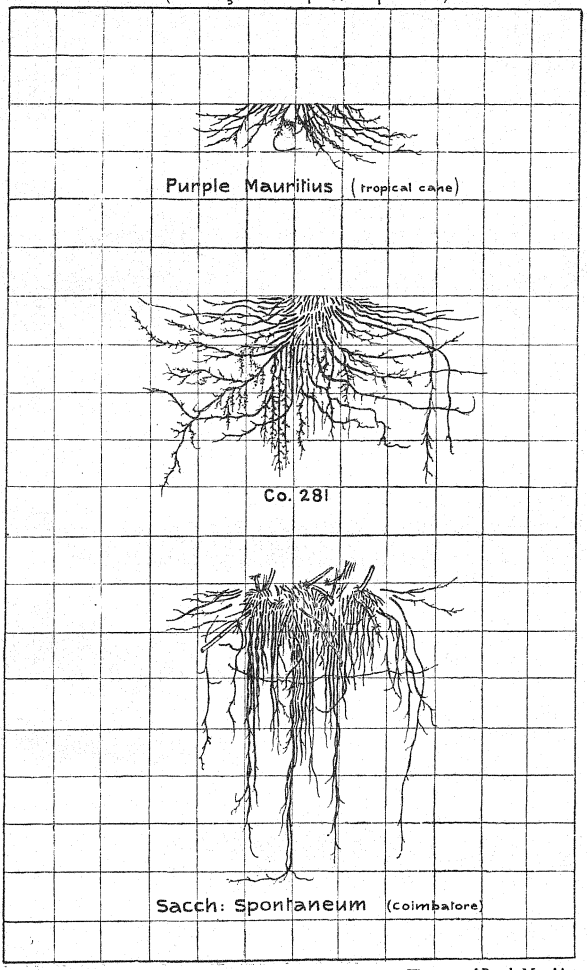
Root systems of sugarcanes show characteristic differences according to the variety to which they belong; and a knowledge of their mode of development is often useful in deciding about the suitability of a new cane to a given set of conditions.

Most tropical types have developed a comparatively surface system necessitating a high type of cultivation for their successful growth. Most Indian canes, on the other hand, develop a deeper system and possess besides, other characteristics which render it possible to grow them under comparatively unfavourable conditions. An ideal root system, conducive to the obtainment of maximum results, would be one which is able to tap the surface as well as the deeper layers of soil for plant food. Somewhat of an approach to this ideal—*viz.*, the root system of Co. 281—is figured in Pl. VI. The root systems of a tropical cane (Purple Mauritius) and the grass *Sacch. spontaneum*—all grown under the same conditions—have also been included in the Plate for comparison.

It should ultimately be possible to work out for each cane its characteristic root system which, besides indicating the conditions under which the variety is likely to do its best, would help to guide the cultivation operations with the maximum of advantage to the crop. For instance, if it is known when and where a particular variety under cultivation develops its series of new roots, the manuring and cultural operations could be timed with the maximum of advantage to the growi crop. It needs to be mentioned, however, that the task is rather laborious, as the root development is profoundly and continuously influenced by environmental conditions; and a very large number of dissections under different conditions of growth would be needed to arrive satisfactorily at the typical root system of a given cane. Though the task is a laborious and time consuming one, it is well worth doing, because of its practical utility in agricultural operations.

Adult Root systems

(Back ground foot squares)



Note the marked difference in the three root systems shown above. The roots of Purple Mauritius are shallow, and of *Sacch. spontaneum* deep. Co. 281—which, in the words of Dr. Earle, has established at Cuba " a record of which any variety may well be proud " possesses shallow as well as deep roots. One of the great grand parents of Co. 281 is *Sacch. spontaneum* ; and it is suggested that the deep roots are derived from this parentage. **Hybridization of sugar canes with the object of securing a desirable root system is a promising line of work for the future.**

IV. Sett versus Shoot roots.

In the earlier sections of this paper the roots of the sugarcane plant were classified (we believe with some justification) into "*Sett*" and "*Shoot*" roots. We now propose to consider the main differences between the two kinds of roots and seek for any reasons that might explain the observed differences.

(1) *Points of difference.*

(*a*) *Thickness.* One readily noticed difference between sett and shoot roots is the greater thickness of the latter (Frontispiece). Amongst the shoot roots themselves there is often a gradual increase in thickness as the plant advances in growth. The shoot roots arising from the "daughter" shoots are thicker than those from the "mother" shoot, those from the "grand-daughter" shoots still thicker than those from the "daughter" shoots and so on (Frontispiece)[1]. An increase in thickness means an increase in circumference, a corresponding increase in root surface and hence again in the number of root hairs that can be developed. As the absorptive power of roots depends ultimately on the number of root hairs developed—other things being equal—it is evident that as absorptive organs the shoot roots are better organized than sett roots.

When it is remembered that there exists a considerable quantity of plant food stored in the joints or internodes of the planted sett, it is admissible to suggest that the sett roots have another function besides the absorption of plant food from the soil. Anchorage suggests itself, as one watches setts germinating on the sides of a rapidly flowering irrigation channel or other watercourse. The arrangement of these roots in the form of a circle round each node would enable them to perform this function in an admirable manner.

(*b*) *Power of soil penetration.* The shoot roots possess larger and, apparently also, stronger root caps than sett roots and are able to pierce the soil with greater ease.* Their greater thickness and the vigour with which they are developed render them efficient as piercing organs. A more detailed study of the histology and physiology of sugarcane roots is now in hand; and it is hoped later to make this the subject of another publication.

(*c*) *Density.* If at any stage the sett and shoot roots of a cane plant are separately collected, it is found that the shoot roots are lighter than the sett roots which are more fibrous (Table IV). Though regular weights have not been recorded, it is probable that the later formed shoot roots would be lighter than the earlier ones.

(*d*) *Growth.* But perhaps the most important difference between the two classes of roots—a difference which is of importance in the growth of the plant—is their

[1] Venkatraman, T. S., and Thomas, R. Sugarcane Breeding Technique—Isolation of live arrows from undesired pollen through artificial rooting of canes. *Agri. Jour. India*, Vol. XXI, pt. 3, Plate VI.

* Differences have been noticed between shoot roots of different varieties in their power of penetration into various soils.

relative power of growth. Under ordinary crop conditions, the two classes of roots become intertwined with one another and it is not possible to separate them easily with much claim to accuracy. With the special method of the Junior author already referred to, it is now possible to grow the two classes of roots altogether separate from each other and even feed them in two different ways, if the plan of the experiment needed it. Plate VII, Figs. 1 to 5 illustrate the greater amount of growth from shoot roots as compared with that from sett roots. Two plants of Co. 213 were first started on sett roots from the bottom nodes, the setts—two budded setts in this case—being planted vertically in pots. Fig. 1 represents the growth from the sett roots of the bottom nodes and it will be noticed that they are about equal in the two top plants in Plate VII. Fig. 2 represents growth from 6 sett roots developed from the top node and Fig. 3 growth from two shoot roots developed from the top node of the second plant during the same period. A similar result was obtained—perhaps in a more striking manner—by growing a third plant on all the sett roots developed from the bottom joint during the first two months and subsequently throwing the plant for a further period of two months on a couple of shoot roots developed from the top node. It is unfortunate that weights were not recorded at the time, but the pictures, drawn from photographs, are fairly conclusive. Over a dozen plants grown in the above manner gave similar results.

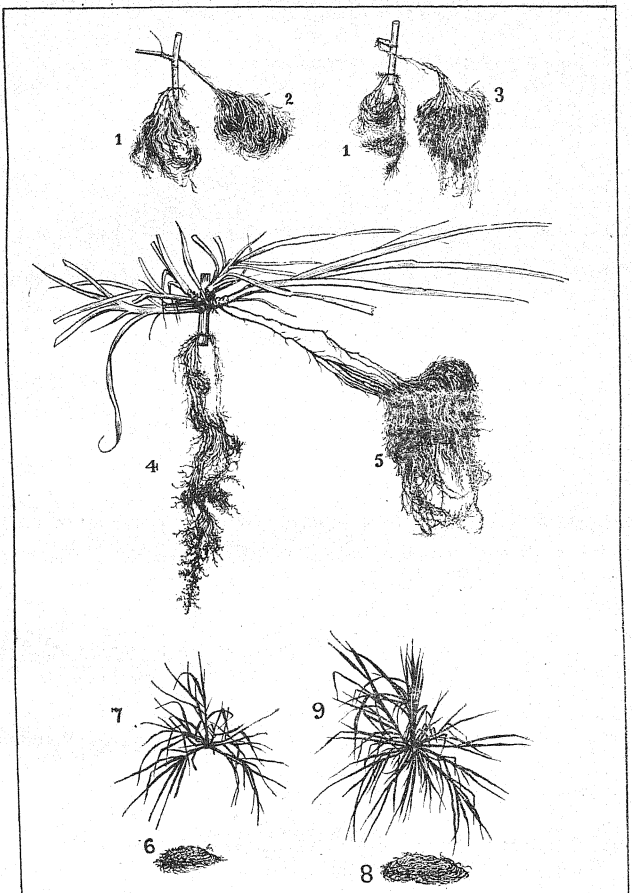
TABLE IV.

Relative densities of sett and shoot roots.

Name of variety	Age of plant at time of examination	Density of roots	
		Sett	Shoot
	Days		
Katha	58	0·20	0·13
	78	0·33	0·18
	104	0·33	0·19
Saretha	58	0·17	0·12
	81	0·25	0·16
	104	0·20	0·17
Hemja	60	0·16	0·15
	81	0·21	0·16
	105	0·33	0·17
247-B	62	0·17	0·13
	82	0·14	0·15
	109	0·22	0·17
E. K. 2	64	0·19	0·12
	83	0·22	0·16
	110	0·26	0·17

SETT versus SHOOT ROOTS---DIFFERENCES in GROWTH

(PLANT STUDIED Co. 213)



1. Mass of sett roots from bottom node on which the plants (not seen in the picture) were originally started. 2. Three months growth of sett roots from top node. 3. Three months growth of shoot roots from top node. 4. Two months growth from a large number of sett roots. 5. Two months growth from a couple of shoot roots. 6. Root growth during four months, when the plant was made to depend on sett roots alone, the shoot roots being removed as they were formed. 7. Shoot of the above plant at four months. 8. Root growth during four months, when the plant was allowed both sett and shoot roots. 9. Shoot of the above at four months.

Note.—The plants 6 to 9 are not comparable with the others in the plate.

Shoot roots of canes have a greater vigour of growth than sett roots.

(2) *Suggested reasons for the observed differences.*

While the shoot roots are markedly different from sett roots in both appearance and functions, a little consideration will show that they are after all similar to one another. A sett is really a piece of cane (as used in planting over the bulk of India), generally full grown, and carrying three buds. While examining the origin and development of shoot roots, it was observed that the shoot roots also had their origin from canes, though in a rather incipient state.

The sett roots are formed from fully formed canes, the canes themselves being in a dormant condition with dormant buds and root eyes. The shoot roots, on the other hand, take their origin from canes which are actually developing and consequently in an active state of growth. Secondly, the sett roots arise from canes which have no leaves attached to them. The canes producing shoot roots, on the other hand, are in organic connection with actively functioning and assimilating leaves; and it is therefore admissible to presume that these canes have circulating in them plant food in a form available for immediate use. The above differences are, in the opinion of the authors, adequate to explain the differences observed between the two kinds of roots. The fact that amongst the shoot roots themselves the late formed—*i.e.*, those formed when the plant is in a more active and advanced state of growth—are thicker than the earlier formed shoot roots lends some support to the above view.

(3) *Experimental evidence in support of (2) above.*

If, as has been assumed, the condition of the canes at the time of root formation is largely responsible for the differences noticed, one should be able to obtain from the root eyes of a sett—which, instead of being dormant, possesses organic connection with actively functioning leaves—sett roots thicker and stronger than ordinary sett roots and rather comparable to shoot roots.

For this purpose a cane sett of seven joints was planted vertically in a pot, the bottom node alone being buried under the soil at the start of the experiment. All the buds in the sett were carefully removed except the top one, the root eyes being left intact in all the nodes. After a time and with the ordinary treatment, roots developed from the buried node much like ordinary sett roots (Pl. V, 1, (*b*)). With this development of sett roots, the top bud—the only bud on the sett—sprouted and after some time developed a shoot with active leaves. At this stage certain of the nodes above the bottom node (already in the soil) were treated for root development; and the roots thus developed (Pl. V, 1 (*a*)) were distinctly thicker than those of the bottom node and appeared to be more vigorous as well.

V. Certain interesting characteristics of sugarcane roots.

In the course of these investigations, sundry interesting characteristics of sugarcane roots were met with; and it is proposed to deal very briefly here with two of the more important of these.

(1) *Aerotropism.*

Roots of most cane varieties are positively aerotropic. There are, however, interesting differences between varieties in this respect, which are well brought out when canes are grown in water culture. The sett roots of Striped Cheribon, for instance, are more aerotropic than those of Katha—an Indian cane not quite intolerant to water-logging (Pl. VIII, Figs. 1 and 2). In both Hemja (an Indian cane commonly grown in the Gangetic plain) and in Badila, the branches arising from the first formed sett roots are aerotropic (Pl. VIII, Figs. 3 and 4). Fig. 5 in the same Plate shows the roots of another tropical cane—Red Sport of Striped Mauritius—growing towards the surface of the soil in the plot.

The grass *Sacch. spontaneum* is able to grow under water-logged conditions and seedlings derived from it have shown similar resistance to water-logging. The authors have derived useful indications in this matter from plants grown in water culture. Compared with Indian canes, the tropical kinds are more difficult to grow in water culture, some of them often dying after four to six weeks. Certain seedlings derived from *Sacch. spontaneum* have been known to grow in water culture solutions and with but little attention for over eight months.

(2) *Adaptations for rooting efficiency.*

Pl. IX, Figs. 1 and 2 show a rather interesting adaptation by which the roots of a shoot, growing well above the soil, manage to reach to it. The roots first produced from the above-ground shoot in Fig. 1 became dwarfed, apparently on account of their inability to function properly. Further roots were successively developed from the shoot and met with a similar fate, till the mass of roots almost reached to the soil and formed in effect a kind of bridge between the shoot and the soil. The latest roots to be developed reached the soil over this mass of roots (Pl. IX, Fig. 2). Once the soil was reached, the roots grew in the normal manner.

Yet another adaptation conducive to rooting efficiency is the depressed habit of the first formed shoots. Such a habit almost buries the shoot—and hence the incipient cane in the shoot—into the soil, thus contributing to an early development of roots and tillers from the first formed shoots. Pl. IX, Fig. 3 shows three such depressed shoots in darker lines.

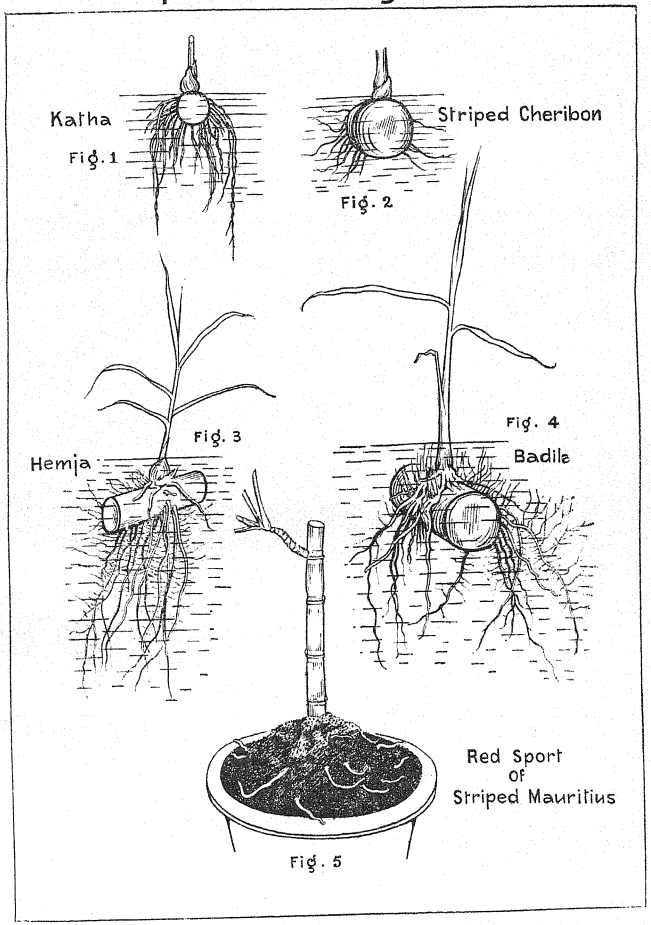
VI. Summary and Conclusion.

During the germination or sprouting of sugarcane setts, the development of roots from the dormant root eyes is one of the first activities.

The roots thus developed from setts have been styled "*sett*" roots in contrast to "*shoot*" roots which are developed later from the shoots.

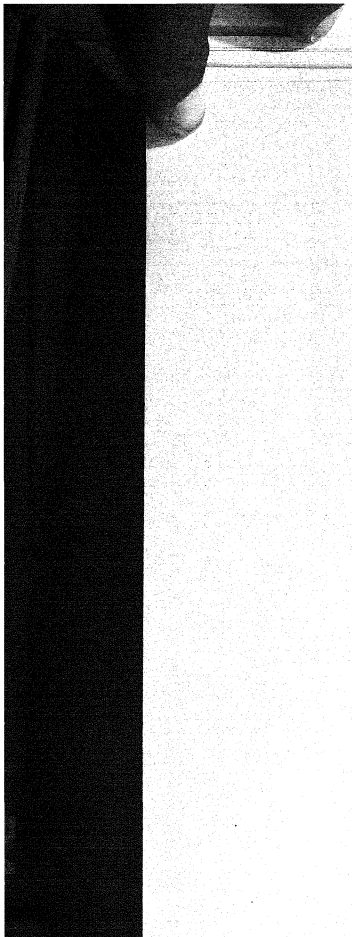
There is no correlation between sett root production and the sprouting of buds. For the full development of the bud into a shoot, however, sett roots are *essential.*

Aerotropism in Sugarcane roots.



1 to 4 were grown in water culture.

Sugarcane varieties differ in the relative resistance of their roots to water-logging. Before introducing a new cane into a locality liable to water-logging, its root behaviour to such conditions should be studied to avoid disappointment. Quite recently the senior author recommended a cane to such conditions on the strength of its root behaviour in water culture, and the cane has since proved a success.



Adaptations for rooting efficiency

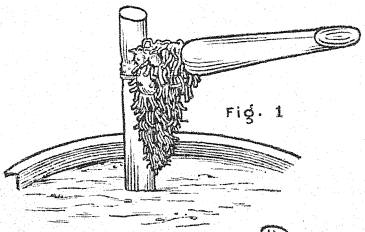


Fig. 1

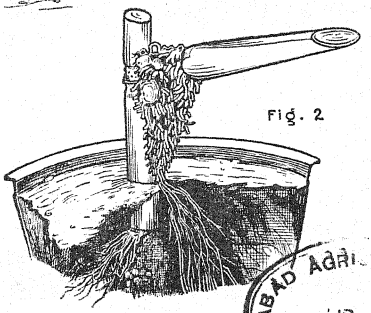


Fig. 2

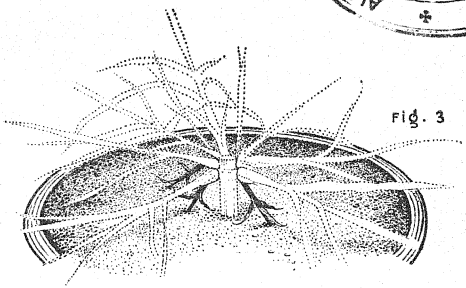


Fig. 3

Figs. 1 and 2 show how the dwarf aerial roots from an above-ground shoot form a kind of bridge for the latter developed roots to reach to the soil.

Fig. 3 shows how the depressed habit of early shoots presses the shoots (darker lines) into the soil. This helps tillering: varieties which have a depressed habit in the early stages, not only keep down weeds by covering the ground, but sometimes prove good tillerers as well.

Interesting differences exist between cane varieties in the number, length and functioning period of sett roots produced during germination. In certain canes only a portion of the root eyes produce roots, the rest remaining dormant till a need arises. This is considered to be a definite and valuable provision against possible adverse conditions during the later stages of growth.

Irrigation with saline water is harmful to sett root development and should be avoided.

In most canes, sett roots die after a time and, subsequent to this, the plants are dependent on " shoot " roots developed later from the young growing shoots.

The rate of growth of the above ground portion of the cane plant is positively correlated with the growth vigour of shoot roots and the study of these roots thus becomes a matter of great importance to the cane grower.

During the adult stage of the cane plant there is almost a continuous development of new roots, resulting in a constantly changing root system which readily adjusts itself to changes in the environment.

If the cane is prevented from thus developing new roots, it gradually loses vigour and dies.

It is desirable to work out for each variety its typical root system and find out exactly where (in the soil) and when the series of successive new roots are developed. Such knowledge would materially help in indicating beforehand the conditions under which the variety is likely to do its best. It would further be of great use in guiding manurial and cultural operations with the maximum advantage to the growing crop.

Sett roots differ from *shoot* roots in certain respects, the generally greater growth vigour of the latter being the most important difference.

The observed differences between the two classes of roots arise, it is suggested, from differences in the condition of the canes giving rise to each class.

Certain interesting adaptations in sugarcane roots, such as aerotropic curvatures and arrangements for ensuring an efficient rooting, are briefly described.

The above-ground portions of plants have been receiving attention at the hands of botanists and crop specialists for some considerable time. It is only in recent years that some attention—by no means adequate—has been directed to the study of the chief underground portions of plants, the roots. To the agriculturist the study of roots is of paramount importance, as it is only through them and with their help that it is, generally, possible to influence the growth and production of the above, ground portions, which supply practically the whole of the food required by man and beast. The data presented in this paper have indicated certain of the directions in which knowledge of roots and root systems would be of direct benefit to the cane grower. Better and more work is needed to fully understand and influence to the advantage of mankind such a valuable food crop as the subject of this paper, the *sugarcane*.

MGIPC—M—III-1-93—5-3-29—650.

CONTENTS

STUDIES IN INDIAN PULSES.

1. Lentil (*Ervum lens*, Linn.)

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I. Introduction.

Although the lentil is recognised as a valuable pulse grown as a winter crop all over India, little attention has hitherto been paid to this plant. It is known to be the most nutritious of the pulses and is an important item in the diet of some people particularly those of Eastern Bengal.

It is not one of those crops of which separate statistical records are kept, and hence it is difficult to estimate the correct yield and area. It is cultivated, however, in all parts of India either as a separate or as a mixed crop, and its economic importance justifies a careful study of the plant.

According to De Candolle[1] " ..... The lentil appears to have existed in Western temperate Asia, in Greece and in Italy, where its cultivation was first undertaken in very early pre-historic time, when it was introduced into Egypt. Its cultivation appears to have been extended at a less remote epoch, but still hardly in historic time, both east and west, that is into Europe and India. ....." " Adolphi Picket quotes a Persian name, '*mangu*' or '*margu*,' but he does not say whether it is an ancient name existing, for instance, in the Zend Avesta. He admits several Sanskrit names for the lentil, *masura*, *renuka*, *mangalya*, etc., while Anglo-Indian botanists, Roxburgh and Piddington, knew none. As these authors mention an analogous name in Hindustani and Bengali, *mussour*, we may suppose that *massour* signifies lentil, while *Mangu* in Persian recalls the other name *mangalya*. As Roxburgh and Piddington give no names in other Indian languages, it may be supposed that the lentil was not known in this country before the invasion of the Sanskrit speaking race. As an article of food, it has been known from the most ancient times." In India the lentil is eaten as *dal*, flavoured with various aromatics and condiments, also as a component part of the dish called *khichri*. The young pod

[1] De Candolle, *Origin of Cultivated Plants*, 1904, p. 321.

is also eaten as a vegetable, and the dry leaves and stalks are greatly prized as fodder. In Europe this pulse meal, mixed with barley flour or other cereal and common salt, is sold as an invalid food under the name Ervalenta or Revalanta.[1]

The following chemical analysis is given by Leather [2]:—

	Per cent.
Moisture	8·03
Oil	1·06
Albuminoids	23·00
Soluble carbohydrates	61·14
Woody fibre	2·42
Soluble mineral matter	3·54
Sand and silica	0·81
Total nitrogen	3·94
Albuminoid nitrogen	3·68

Although it is cultivated to some extent outside India, the only references of any importance available regarding its cultivation are in the American literature. No attempt appears to have been made anywhere to isolate and describe the elementary species of which the crop is composed. Fruwirth [3] has attempted to separate lentil types according to the seed colour and has given a good description of the flower and the method of pollination.

A case of parallel variation in vetches and lentils is described by Vavilov.[4] Vetch (*Vicia sativa* Linn.) is often found as a weed in lentils and certain varieties of vetch are so similar to lentils in shape, colour and size of seed that they cannot be separated in sorting. These vetches also often flower and fruit at the same time as lentils and are, in fact, perfect "mimics" of the lentils. The whole series of varieties in these two genera show clearly that it is difficult even for an expert to separate several varieties of lentils and vetches by their seeds alone and, moreover, in the colour of their flowers and in many other characters lentils show a similar series of variations to vetches. Selection in lentil seed has, therefore, led to the rejection of all vetches except those which were closely similar to the lentil type; these vetches will persist as an impurity in lentils and can only be eliminated by raising pure line cultures of lentils.

Lentils—*Ervum lens*, Linn., *Lens esculanta* Moench., *Cicer lens*, Willd., *masur*, *channangi*, *mohr*, *chanching*, *kerze*, *adah*, *misurpurpur*, *misur-pappu*, etc.—belongs to the natural order *Leguminosae*, sub-order *Papilionaceae*, tribe *Viceae*, and is a small softly pubescent herb. The genus contains only one species and no references to the varieties and unit types of which this crop is composed can be traced. The existence of more than one variety of this species has been recognised by the Director of Land Records and Agriculture, Bengal [5] who reported the occurrence of two varieties of *Ervum lens* grown in Dacca; one was the Patna variety, and the other was found in Lower Bengal. The plants of the latter were said to be bushy

[1] Watt. *The Commercial Products of India*, 1908, p. 709.
[2] Indian Food Grains and Fodders. *Agri. Ledg.*, 1901, No. 10, p. 366.
[3] Fruwirth. *Die Zuchtung der landwirtschaftlichen kulturpflanzen* 3, 1901, 146-148.
[4] Vavilov, N. I. The law of homologous series in variation. *Jour. Genetics*, 12, 1912, 47-89.
[5] Watt. *The Commer. Prod. of India*, 1908, p. 709.

and to give a better outturn. G. L. C. Howard and Abdur Rahman Khan[1] also mention that large seeded types of lentil generally belong to the black cotton soil areas, whereas in Bihar the corresponding varieties have very small seeds.

Our detailed study of this crop shows that the Indian lentil crop, like most other Indian field crops, is not uniform but consists of many different forms, distinguished from one another by various morphological and physiological characters.

A collection of mixed bazar samples was made in 1924 from the undermentioned localities and isolation of pure types was continued in the following years. All cultures, as usual, were started from bagged seed of a single plant, and 66 pure types were obtained, some of which show great agricultural promise.

TABLE I.

Locality from which original samples of lentils were obtained and types isolated from them.

Province	Locality	Types isolated at Pusa
Burma	Allanmyo	T. 57.
	Sagaing	T. 56.
Bengal	Birbhum	T. 31 and T. 43.
	Burdwan	T. 7.
	Jessore	T. 55 and T. 66.
	Khulna	T. 6 and T. 47.
	Murshidabad	T. 26 and T. 45.
	Pabna	T. 46 and T. 63.
	Rajshahi	*Nil.*
Bihar and Orissa	Arrah	T. 22.
	Darbhanga	*Nil.*
	Patna	T. 49.
	Gaya	T. 13, 15, 39 and 59.
	Muzaffarpur	*Nil.*
	Sabour	T. 27 and T. 29.
	Sepaya	T. 32.
	Cuttack	T. 44.

[1] Howard, G. L. C., and Abdur Rahman Khan. Studies in Indian Oil Seeds, No. 2. Linseed. *Mem. Dept. of Agri. India, Bot. Ser.*, XII, 4, 1924, p. 183.

TABLE I—*contd.*

Locality from which original samples of lentils were obtained and types isolated from them—contd.

Province	Locality	Types isolated at Pusa
United Provinces of Agra and Oudh	Agra	T. 9.
	Aligarh	T. 18.
	Bulandshahr	*Nil.*
	Gorakhpur	T. 11 and T. 23.
	Lucknow	T. 34 and T. 50.
	Muttra	T. 2 and T. 30.
	Muzaffarnagar	T. 35 and T. 52.
	Partabgarh	T. 16 and T. 48.
Punjab	Ambalia	T. 28.
	Ferozepur	T. 38.
	Gurdaspur	T. 36 and T. 51.
	Karnal	*Nil.*
	Lahore	*Nil.*
	Lyallpur	T. 40 and T. 58.
	Rohtak	T. 65.
N. W. F. Province	Peshawar	T. 53.
Central Provinces	Jubbulpur and neighbourhood.	T. 3, 8, 12, 14, 19, 33, 41, 62 and 64.
Madras	Madras	*Nil.*
	Coimbatore	*Nil.*
Bombay	Bailhongal	T. 25 and 61.
	Mirpurkhas	*Nil.*
	Poona	T. 4 and 54.
	Sholapur	T. 5.
	Surat	T. 1, 17, 37, 42 and 60.
	Wardha.	T. 10 and 24.

Cultivation. Watt [1] states that the lentil is cultivated in all parts of India especially in Bengal, Madras, Central Provinces and the United Provinces of Agra and Oudh. It is sown in all kinds of soils, but chiefly in low-lying land. In Bengal it thrives best on a clay soil, since in light soils the plants wither away. In rotation following paddy, the land receives three or four ploughings and the seed is sown from October to December. Sometimes it is sown mixed with barley. In Assam the crop is reported to prefer a light, loamy soil and an open situation, and generally follows a broadcasted rice crop, and is sown in mixture with mustard. In the United Provinces [2] the cultivation is most extensive in the damper regions and it is sown in all kinds of soil, but chiefly in low-lying land. In the Central Provinces and Berar it is generally sown on the best black soil. In the Punjab it is a *sailaba* or inundation crop, and new alluvial soils or light lands, not good enough for wheat, are selected, while in Bombay it is given a mixed black soil of moderate depth.

Yield. The average yield of this crop is from 8 to 12 maunds per acre and although no definite work is recorded on the selection and isolation of pure types. Church [3] has stated that the yield of lentil may be increased by the selection of seed for sowing, since there are some varieties of lentil, which produce seed weighing twice as much as the small common sort.

The following Table shows the approximate yield of seed in 1928, in tolas (1 lb. =40 tolas), obtained from 20 plants of each of the 66 types of lentils isolated in the Botanical Section.

TABLE II.

Showing the approximate weight of seed taken from 20 plants selected at random from each type.

Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas
Large	41	5	Intermediate	42	6	Small	39	20
	30	7		50	7		56	22
	16	11		37	8		6	27
	13	12		64	9		57	28
	5	13		12	10		66	29
	17	14		1	10		55	30
	14	14		24	11		58	105
	60	15		48	14		40	138
	8	16		21	14		28	245
	29	16		31	15			
	59	17		25	15			
	13	18		54	16			
	15	19		4	19			
	3	20		61	19			

[1] Watt. *Commercial Products of India*, 1910, p. 708.
[2] Duthie and Fuller. *Field and Garden Crops*, Pt. II, p. 13.
[3] Church, A. H. *Food*, 1882.

TABLE II—*contd.*

Showing the approximate weight of seed taken from 20 plants selected at random from each type—contd.

Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas	Size of seed	Type No.	Weight in tolas
Large .	9	71	Intermediate	62	25	Small .		
	20	80		7	25			
	2	102		32	26			
	10	105		26	26			
	19	145		43	27			
				47	28			
				45	29			
				44	30			
				63	30			
				46	36			
				53	50			
				22	106			
				49	125			
				52	135			
				65	145			
				36	150			
				23	150			
				51	150			
				33	150			
				35	190			
				38	195			
				11	195			
				27	205			
				34	225			

From the above Table, it is apparent that there is great diversity in the relative yielding capacity of the different types in all the large, intermediate and the small-seeded varieties, and that from an economic point of view it will be advantageous to conduct varietal trials for yield with types 2, 10 and 19 of the large seeded variety, types 11, 27 and 34 of the intermediate and types 28 and 40 of the small-seeded variety.

All the types which have originated from samples obtained from Burma and Bengal have white flowers and have small or intermediate-sized seed. Two types from Bailhongal and one from Jubbulpur also have white flowers and intermediate-sized seed. None of the large or bold seeded varieties have pure white flowers and the majority of these types have come from Peninsular India. Almost all the heavy yielding varieties, whether small, intermediate or bold seeded, have coloured flowers.

II. GENERAL BIOLOGY.

1. Root System.

The wide range in the soil and agricultural conditions in the localities from which the various mixed samples were drawn suggested that a study of the root systems

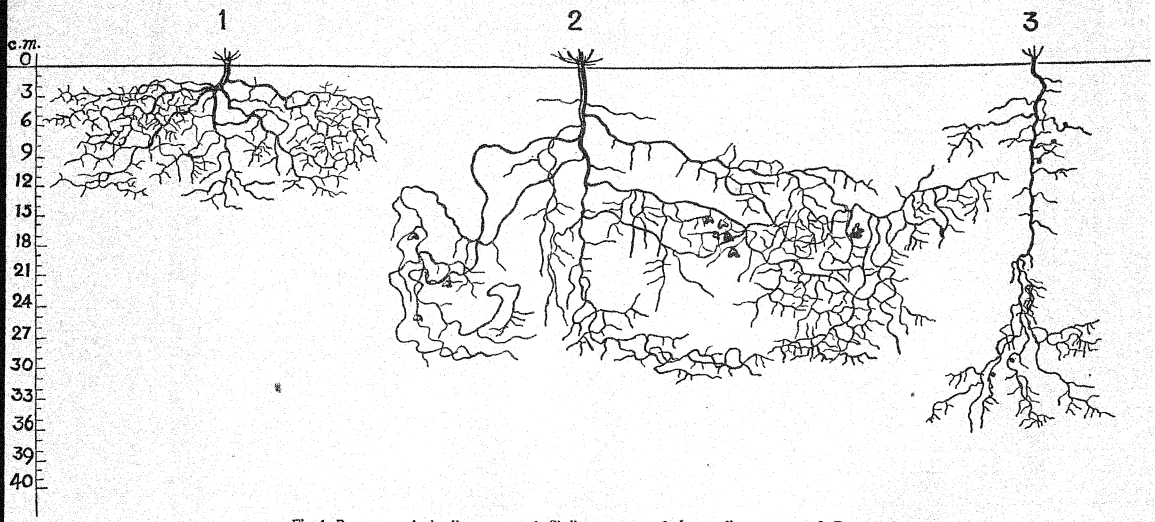

Fig. 1. Root system in lentils. 1. Shallow. 2. Intermediate 3 Deep.

of some types might prove useful. It was interesting to find that the results of such a study confirmed the observations of workers on some other crops such as Linseed and *Khesari* (*Lathyrus sativa*, L.). Three types of root systems were recognised :—

(1) Almost all the types which originated from samples obtained from the black cotton soil areas had a deep root system. Such root systems are often characteristic of crops growing in tracts where the soil surface cracks and rapidly dries and where the crop is dependent mainly on the moisture of the lower layers.

(2) Types obtained from the alluvium showed a well branched shallow root system and abundant healthy root nodules.

(3) Types selected from the Punjab and N. W. F. Province generally showed an intermediate condition.

The deep rooted systems seem to be associated with bold seed and a somewhat sparse branching which results in a low yield, while types with shallow root systems generally have intermediate or small seed, a profuse branching and consequently a comparatively high yield. These facts agree closely with similar observations on linseed and *khesari* [1] and furnish additional evidence of the importance of the root system in selecting unit species of a crop to suit different soil conditions.

In 1926 the lentil crop was very badly affected by Aphids at Pusa, and a close examination showed that the infection varied with the type of the root system—the deep rooted varieties coming from Peninsular India being affected the most and the alluvial types the least. The same phenomenon has been recorded in the case of *khesari* and illustrates how a physiological derangement occasioned by a root system not being adapted to the soil conditions may cause an increased susceptibility to pests and diseases. In the case of the attack of aphids on lentils, the pest was defeated by releasing on the lentil plants a number of lady-bird beetles which are the natural enemies of aphids.[2]

2. *Flowering.*

The flowers are borne singly or in 1, 2, 3, or rarely 4 flowered racemes on short peduncles, which are about as long as the leaves and extend some distance beyond the flowers. The lowermost buds open first and it takes nearly a fortnight for the complete opening of all the flowers on a single branch.

A study of the time of opening of flowers in lentils showed that this phenomenon depended chiefly on the temperature and humidity and is more or less the same in all the types. A number of buds which were likely to open on the next day, were labelled in the evening and observations were made at regular intervals on the next and the following mornings until dusk. In the majority of cases it was found that on a clear day the flowers begin to open at about 8 A.M., but mostly between 9 A.M.

[1] Howard, A. Crop Production in India, 1924, p. 51.
[2] Dutt, G. R. Aphids and Lady-bird Beetles. *Agri. Jour. of India*, XXII, 1927, 291-292.

and 10 A.M., and at times continue to do so till 12 noon. They remain open the whole of that night and the next day and some of them begin to close at or about 4 to 5 P.M., while others struggle on till the next morning. On the third day, however, all of them close completely and the corolla begins to fade. The pod makes its appearance 3 or 4 days later. On a cloudy day, however, the flowers do not open till midday and continue to do so till the evening (5 P.M.) remaining open the whole of the next day and beginning to close on the third day. Flowering begins from the lowest flower and proceeds up the stem.

3. *Pollination.*

The following description of the method of fertilization in lentil is given by Knuth [1] :—

" The bluish-white flowers of the species are marked with blue lines on the vexillum (nectar guides), and a small patch on the tip of the carina (pollen guide). Kirchner (' Flora v. Stuttgart,' p. 508) states that the vexillum, which but slightly ensheaths the other parts of the flower, comes into close contact with the alæ by means of two forwardly directed folds of a projecting ridge. The style bears projecting hairs only on its inner side. Otherwise the mechanism agrees with that of Vicia Ervilia. Kerner says that the flowers are fertile when insect visits are prevented.

Visitors. Herm. Muller saw the honey bee (Skg.) and a butterfly (Cœnonympha pamphilus). ' Weit. Beob.' II, p. 258."

Our observations here confirm this description and we have found that the anthers burst in the bud some time before the opening of the flower. An examination in the evening of 50 young buds which were likely to open the next morning showed this condition in the majority of cases. The different stages in the development of the bud are shown in Plate I.

Bees, small butterflies and numerous ants visit the flowers throughout the day. Seed is set freely under bags and no serious effects, excepting a slight elongation of the nodes and foliage in general, has been observed in plants under bags.

4. *Cross-fertilization.*

Self-fertilization seems to be the general rule with this crop and we have not yet come across any case of natural cross-fertilization. The fact that bees and other insects visit the lentil crop in abundance suggests the possibility that cross-fertilization may take place.

5. *Hybridization.*

Notwithstanding the fact that the flowers of lentils are very small no special trouble is met with in hybridizing different types. A number of crosses have been made to study the genetic relation of different combinations, such as bold × small

[1] Knuth. Handbook of Flower Pollination, Vol. II, p. 329.

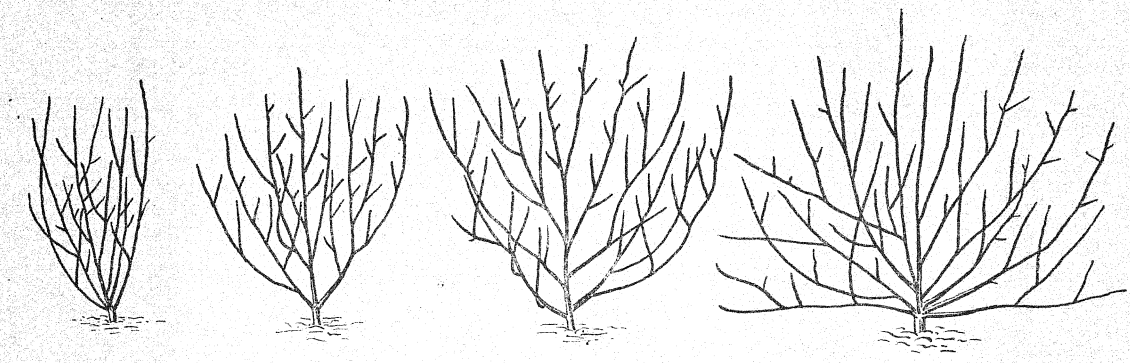

Fig. 2. Showing different modes of branching.

seed, white × coloured flowers, self coloured × mottled seeds, etc., the results of which will be published later. Humidity, however, appears to be a limiting factor in the success of crossing, as hardly any setting takes place when the hybridized flowers are covered with ordinary manilla paper bags, while no difficulty is experienced when they are covered with small muslin bags which provide sufficient æration.

III. Classification and Description of the Types.

Sixty-six unit species of lentil have been isolated from the original mixed seed samples. The chief morphological characters in which these types differ are :— (1) Size, colour and markings of the seed ; (2) colour of the flower ; (3) time of flowering as measured by the opening of the first flower ; (4) habit ; (5) colour of the leaf ; and (6) colour of the stem.

Prain [1] describes this genus as follows :—

"218, LENS, Gren. & Godr. Annual herbs, erect or subscandant ; *leaves* usually even-pinnate, the rachis ending in a tendril or a simple point occasionally with a terminal leaflet ; stipules semisagittate, stipels O. *Flowers* axillary, peduncled, solitary, or in few-flowered racemes ; bracts and bracteoles usually O. *Sepals* connate in an oblique tube, lobes 5, elongate, subequal. *Petals* exserted, standard broad, narrowed to a very short, wide claw ; wings oblong, oblique, adnate in their middle to the shorter keel. *Stamens* 10, the vexillary one free, the others connate in an oblique sheath ; anthers uniform. *Ovary* subsessile, 2-ovuled ; style inflexed, bearded longitudinally on the inner face ; stigma terminal. *Fruit* a compressed 1-2 seeded pod, continuous within. *Seeds* compressed lenticular; hilum ovate or oblong."

This description fits generally all the unit species described in this paper, but for the separation of the types, we must consider the characters in greater detail.

Habit. The general habit depends on three things—the height, the mode of branching and the foliage. The height of the various unit species seems to be influenced by the environment and as it does not vary much in the different types it has not been taken as a differentiating character. The basal branches may be crowded giving an erect, more or less compact appearance (Fig. 2—I) ; they may be semi-erect and somewhat open (Fig. 2-II) ; spreading and very much open (Fig. 2-III) ; or more or less trailing on the ground (Fig. 2-IV).

The nature of the branching is useful as a minor distinguishing character. The branching may be profuse or sparse. The size and form of the leaflets also influence the habit of the plant.

Maturity. The types show very great differences in the length of their growing period as well as in the time at which they start flowering. In 1927-28 the earliest type began to flower on the 4th December 1927 and the latest on the 18th February 1928 showing a very wide range indeed. The crop was sown on the 25th October

[1] Prain, D. *Bengal Plants*, Vol. I, 1903, p. 367.

1927. Types which started flowering from the 8th to the 10th week after sowing have been classified as very early ; those which started from the 11th to the 13th week were considered to be early ; those between the 14th and the 16th week were counted as medium in maturity ; those between the 17th and 18th week were taken to be late, while those which flowered later than this were classified as very late (Table III).

TABLE III.

Maturity of different types as measured by the date of the first flower.

Very early	Early	Medium in maturity	Late	Very late
8th to 10th week after sowing	11th to 13th week after sowing	14th to 16th week after sowing	17th to 18th week after sowing	19th week or later after sowing
Types	Types	Types	Types	Types
2, 4, 5, 7, 8, 10, 13, 16, 17, 25, 29, 30, 31, 37, 39, 41, 43, 44, 45, 48, 54, 55, 56, 61, 64, 66.	1, 3, 6, 9, 11, 12, 14, 15, 18, 19, 20, 21, 22, 24, 26, 27, 32, 33, 42, 46, 47, 49, 50, 57, 58, 59, 60, 62, 63.	23, 28, 34, 35, 38, 51.	36, 52, 65	40, 53

Stem. The stem is usually much branched from the base, and is generally furrowed, angular, and hairy. It may be purely green or may have splashes of red colour at the base in addition.

Leaves. The types differ considerably both in the total length of the leaf, in the size and number of leaflets as well as in the tone of the colour of the foliage. The total length of the leaf has been used for describing the leaves as small (1·5 cm. to 2·1 cm.), medium (2·1 to 2·7 cm.), and large (2·7 cm. to 3·8 cm.). The average number of leaflets per leaf is also mentioned in the description of the types, and whenever the leaf has terminated in a small tendril a note to that effect has been made. In all other cases a tendril, which is nearly as long as the leaf is present. The leaflets are beset with fine hairs but there are no glandular knobbed hairs as are present in the case of gram. The foliage colour in the various types has been classified as yellowish green (T. 2) ; light yellowish green (T. 4) ; green (T. 44) ; dull green (T. 17) ; dark green (T. 7) ; and dark bluish green (T. 6). The shades of different colours observed in mass are shown in Plate II. These small coloured differences are best studied when the types are massed together and examined in the early morning or late evening light with the rays of the sun slanting and the sun behind the observer. At times a clear difference has also been observed at or about midday with the sun directly overhead.

Flowers. There is a very slight difference in the size of the flowers. The width of the standard ranges from 0·4 cm. to 0·5 cm. only, and hence this character has not been used for distinguishing types. The colour of the flower is a more important item and is described as :—

(1) *white*—when they are almost white with sometimes a suggestion of a slight trace of pink.
(2) *white with lilac colour on the veins of the standard only*, and a small blue patch on the tip of the carina.
(3) *pink.*
(4) *violet with a pinkish tinge.*
(5) *violet with a light pinkish tinge.*
(6) *violet.*
  (*a*) grade 1.
  (*b*) grade 2 (lighter than grade 1).

The important colour differences in the flower of lentil are shown in Plate III.

Kirchner [1] suggests that the blue lines on the vexillum (like those present in Flower class 2 above) are suggestive of nectar guides, and a small blue patch on the tip of the carina is probably the pollen guide.

The occurrence of 1, 2, 3, or rarely 4 flowers per peduncle was at first thought to furnish an important distinguishing character. But the variation from plant to plant in the same pure line culture was found to be so very great that this character was rejected in the classification. In different plants of the same pure line peduncles with 1, 2, or 3 flowers may be present in varying proportions (Table IV below), and although indications can generally be obtained which show whether the majority of peduncles in a particular type are 1, 2 or 3 flowered no definite and reliable conclusions can be based on this character.

TABLE IV.

Statement showing the number per plant of 1, 2 or 3 flowers on a peduncle in some lentil types.

Type	No. of flowers per peduncle												Total number of plants
	1	Nil	Nil	Nil	Very few	Very few	Very few	Few	Few	Few	Many	Many	
	2	Few	Many	Many	Many	Many	Many	Nil	Many	Many	Many	Few	
	3	Many	Few	Nil	Nil	Very few	Few	Many	Nil	Very few	Nil	Nil	
7		1	1	1	6	2	1	..	10	4	..	1	27
8		..	..	4	13	1	..	..	10	..	..	1	29
21		..	..	3	9	..	1	..	8	1	..	..	22
22		..	..	..	2	1	..	..	18	..	1	..	22
25		..	..	..	3	..	..	21	..	2	1	..	27

[1] Knuth. *Handbook of Flower Pollination*, Vol. II, p. 329.

Pods. These are rhomboid-oblong, smooth, compressed and tipped with the base of the style. They are described as bold, medium or small, according to their size, but these differences are not very appreciable and the character of the pod has not been used for distinguishing the types from one another.

Seed. This has furnished the most important character in the classification of the different types.

(1) *Size.* Three grades in the size of the seed have been distinguished and have been termed large, intermediate and small.

(2) *Ground colour.* This may be :—

(*a*) Prussian red (T. 1).
(*b*) Salmon buff (T. 2).
(*c*) Vinaceous buff (T. 3, 4, and 5).
(*d*) Vinaceous pink (T. 6).
(*e*) Buff pink (T. 7).
(*f*) Pale pinkish buff (All other types).

These colours are not very clear to the naked eye but can be made out when the seed is examined under the binocular. The higher the power of the lens, however, the lighter the tint appears, and hence all descriptions in the following pages are based upon the examination of the material with Zeiss Paired Eyepiece 4, and Objective 3, Magnification×12, and when any comparison is to be made this magnification should be used. Ridgway's[1] colour book has been used for determining the various grades of ground colour.

(3) *Markings.* With the exception of a very few self coloured seed types, the majority have markings covering the whole of the ground colour, which therefore in some cases looks almost black to the naked eye, but examination with a lens shows clearly that the apparently uniform black colour is really due to the crowding together of a large number of dots or patches which for the sake of convenience have been distinguished into two kinds :—

(*a*) Cloudy mottling which has more or less a continuous pattern made up of small dots, violet to ivory black in colour, between which minute areas of the ground colour can be seen with the aid of the lens. Three grades have been recognised—Grade 1 when the mottling is sparse ; Grade 2, medium, when mottling is present uniformly, and Grade 3 when mottling is heavy.

(*b*) Sky-grey specklings which take the form of discontinuous spots much larger in size and unevenly distributed. Three grades of this too have been identified,—Grade 1 when the speckling is occasionally present and is rather sparse ; Grade 2 when the speckling is uniformly distributed and Grade 3 when the speckling is heavy.

Both cloudy mottling and sky-grey speckling occur simultaneously in all but a few types, and at times are intensified to such a degree that the entire seeds are coloured black or violet.

[1] Ridgway, R. *Colour Standards and Colour Nomenclature*, Washington.

(c) The hilum may be pale yellow without any markings or may be speckled at the micropylar end. At times this mark is very prominent (T. 41).

The ground colour and the markings described above are invariably always localised in the testa and do not extend to the cotyledons which generally have the usual characteristic pinkish yellow colour.

The seed colour in lentil does not show any correlation with the flower colour such as has been observed in *Pisum* and *Lathyrus sativus*. Thus in the peas the colourless testa is invariably associated with white flowers (with the exception of a few light-green seeded varieties),[1] while in *Khesari*[2] (*Lathyrus*) all the types with coloured flowers possess seed with mottling or marking on the seed coat. Plate IV shows the important colour patterns present on the seed of lentils. The seed is always compressed, smooth and lenticular, and when fully developed has nothing like the wrinkled forms found in peas and gram.

The amount of mottling or speckling and even the depth of the general colour vary with the age of the seed and indeed mottling and speckling are not fully developed until the seed is mature. Seed examination must therefore be done in mass and full weight must be given to possible differences in maturity. This probably explains the divergent results obtained by Fruwirth[3] in the experiments in which he attempted to separate types according to seed colour.

Our thanks are due to Mr. Sawan Mal Sikka, B.Sc. (Agr.), one of the post-graduate students in the Botanical Section, Pusa, for valuable help in this work, especially in colour determination of foliage, flowers and seed and their classification.

2. Key to the Types of *Ervum lens*, Linn.

I. Seeds Prussian Red.

(A) Seeds not mottled.

a. Speckling occasional (grade 1).

1. Hilum pale yellow.

(i) Seeds intermediate in size.

(1) Flowers pink . . . . . Type 1.

II. Seeds Salmon Buff.

(A) Seeds not mottled.

a. Speckling occasional (grade 1).

1. Hilum speckled at the micropylar end.

(i) Seeds large.

(1) Flowers white with lilac colour on the veins only . . Type 2.

[1] Wellensiek, S. J. Genetic Monograph on Pisum—*Bibliographia Genetica*, II, 1925, 343-473.

[2] Howard, G. L. C., and Abdul Rahman Khan. The Indian Types of *Lathyrus sativa*, *Mem. Dept. of Agri. India, Bot. Ser.*, XV, 1928, No. 2.

[3] Fruwirth. *Die. Zuchtung der Landwirthschaftlichen Kultur* (*pf lanzen*,) 3, 1910.

III. Seeds Vinaceous Buff.

(A) Seeds not mottled.

a. Speckling occasional (grade 1).

1. Hilum speckled at the micropylar end.

(i) Seeds large.

(1) Flowers white with lilac colour on the veins only . Type 3.

(ii) Seeds intermediate in size.

(1) Flowers white with lilac colour on the veins only . Type 4.

(B) Mottling sparse (grade 1).

a. Speckling occasional (grade 1).

1. Hilum speckled at the micropylar end.

(i) Seeds large.

(1) Flowers white with lilac colour on the veins only . Type 5.

IV. Seeds Vinaceous pink.

(A) Mottling sparse (grade 1).

a. Speckling rare.

1. Hilum pale yellow.

(i) Seeds intermediate in size.

(1) Flowers white . . . . . Type 6.

V. Seeds Buff pink.

(A) Mottling heavy (grade 3).

a. Speckling sparse (grade 1).

1. Hilum pale yellow.

(i) Seeds intermediate in size.

(1) Flowers white. . . . . Type 7.

VI. Seeds Pale pinkish Buff.

(A) Mottling heavy (grade 3).

a. Speckling sparse (grade 1).

1. Hilum pale yellow.

(i) Seeds large.

(1) Flowers violet with a pinkish tinge . . . . Type 8.

(2) Flowers violet, grade 1 . . . . . Type 9.

(3) Flowers violet, grade 2 . . . . . Type 10.

(ii) Seeds intermediate in size.

(1) Flowers violet with a pinkish tinge . . . . Type 11.

(2) Flowers violet, grade 2 . . . . . Type 12.

2. Hilum speckled at the micropylar end.

(i) Seeds large.

(1) Flowers with a pinkish tinge.

(*a*) Plants very early . . . . . Type 13.

(*b*) Plants early

i. Semi-erect . . . . . Type 14.

ii. Spreading . . . . . Type 15.

(2) Flowers violet, grade 1.
(*a*) Plants very early.
i. Spreading.
(α) Leaves yellowish green . . . Type 16.
(β) Leaves dull-green . . . . Type 17.

(*b*) Plants early.
i. Semi-erect . . . . . Type 18.
ii. Spreading . . . . . Type 19.

(3) Flowers violet, grade 2.
(*a*) Plants early . . . . . Type 20.

(ii) Seeds intermediate in size.
(1) Flowers violet with a pinkish tinge.
(*a*) Plants early.
i. Spreading.
(α) Leaves deep yellowish-green . . Type 21.
(β) Leaves green . . . . Type 22.
(2) Flowers violet, grade 1 . . . . . Type 23.
(3) Flowers violet, grade 2 . . . . . Type 24.

*b*₂ Speckling medium (grade 2):
1. Hilum pale yellow.
(i) Seeds intermediate in size.
(1) Flowers white
(*a*) Plants very early, leaves light-green . . . Type 25
(*b*) Plants early, leaves dark-green . . . . Type 26
(2) Flowers violet, grade 1 . . . . . Type 27
(ii) Seed small.
(1) Flowers violet with a pinkish tinge . . . . Type 28.

Hilum speckled at the micropylar end.
(i) Seeds large.
(1) Flowers violet with a pinkish tinge . . . . Type 29.
(2) Flowers violet, grade 1. Type 30.

(ii) Seeds intermediate in size.
(1) Flowers white . . . . . Type 31.
(2) Flowers violet with a pinkish tinge.
(*a*) Plants early.
i. Semi-erect . . . . . Type 32.
ii. Spreading . . . . . Type 33.

(3) Flowers violet, grade 1.
(*a*) Plants medium in maturity.
i. Spreading . . . . . Type 34.
ii. Trailing . . . . . Type 35.
(*b*) Plants late . . . . . Type 36.

(4) Flowers violet, grade 2.
(*a*) Plants very early . . . . Type 37.
(*b*) Plants medium in maturity . . . . Type 38.

(iii) Seeds small.
(1) Flowers violet with a pinkish tinge.
(*a*) Plants very early . . . . . Type 39.
(2) Flowers violet, grade 1.
(*a*) Plants very late . . . . . Type 40.

c. Speckling heavy (grade 3).
1. Hilum speckled at the micropylar end.
(i) Seeds large.
(1) Flowers violet with a pinkish tinge . . . . Type 41.
(ii) Seeds intermediate in size.
(1) Flowers violet, grade 2 . . . . . Type 42.

(B) Mottling medium (grade 2).
a. Speckling sparse (grade 1).
1. Hilum pale yellow.
(i) Seeds intermediate in size.
(1) Flowers white.
(*a*) Plants very early.
i. Semi-erect.
(α) Leaves dull green . . . . Type 43.
(β) Leaves green . . . . Type 44.
(γ) Leaves Dark-green . . . Type 45.
(*b*) Plants early.
i. Spreading . . . . . Type 46.
ii. Trailing . . . . . Type 47.
(2) Flowers violet with a pinkish tinge.
(*a*) Plants very early. . . . . Type 48.
(*b*) Plants early.
i. Semi-erect.
(α) Leaves yellowish green . . . Type 49.
(β) Leaves Dull-green . . . . Type 50.
(3) Flowers violet, grade 1.
(*a*) Plants medium in maturity . . . . Type 51.
(*b*) Plants late . . . . . Type 52.
(4) Flowers violet, grade 2.
(*a*) Plants very early.
i. Semi-erect.
(α) Leaves yellowish green . . . Type 53.
(β) Leaves light-green . . . Type 54
(ii) Seeds small.
(1) Flowers white.
(*a*) Plants very early.
i. Semi-erect . . . . . Type 55.
ii. Spreading . . . . . Type 56.
(*b*) Plants early . . . . . Type 57.
(2) Flowers violet with a pinkish tinge. . . . . Type 58.

2. Hilum speckled at the micropylar end.
   (i) Seeds large.
      (1) Flowers violet, grade 1 . . . . . Type 59.
      (2) Flowers violet, grade 2 . . . . . Type 60.
   (ii) Seeds intermediate in size.
      (1) Flowers white.
         (*a*) Plants very early . . . . . Type 61.
         (*b*) Plants early.
            i. Spreading . . . . . Type 62.
            ii. Trailing . . . . . Type 63.
      (2) Flowers violet, grade 1.
         (*a*) Plants very early . . . . . Type 64.
         (*b*) Plants late . . . . . Type 65.
   (iii) Seeds small
      (1) Flowers white . . . . . Type 66.

III. Description of Lentil Types.

Type 1.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Large (3·1 and 1·4× 0·4) green ; 6 pairs of leaflets.

Flowers.—Pink.

Pod.—Bold (1·5×0·5).

Seed.—Intermediate, prussian red, no mottling, occasional speckling, pale yellow hilum.

Type 2.

Habit.—Very early, spreading very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·5×0·4) yellowish green, 6 pairs of leaflets.

Flowers.—White with lilac colour on the veins only.

Pod.—Bold (1·5×0·6).

Seed.—Large, salmon buff, no mottling, occasional sky-grey speckling, grade 1, but always with a speckle at the micropylar end of the hilum.

Type 3.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·2×0·4) yellowish green, 7 pairs of leaflets.

Flowers.—White with lilac colour on the veins only.

Pod.—Medium (1·4×0·6).

Seed.—Large, vinaceous buff, no mottling, occasional sky-grey speckling grade 1, but always with a speckle at the micropylar end of the hilum.

Note.—All measurements are in cm. In the description of the leaf the first number mentioned is the length of the leaf, the second number is the length of the leaflet and the third number is the breadth of the leaflet. Similarly, in the description of the pod the numbers refer to the length and breadth of the green pod.

TYPE 4.

Habit.—Very early, spreading, very much open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·3 and 1·2×0·4), light yellowish green, 5 pairs of leaflets.
Flowers.—White with lilac colour on the veins only.
Pods.—Medium (1·3×0·5).
Seed.—Intermediate, vinaceous buff, no mottling, occasional speckling grade 1, but always with a speckle at the micropylar end of the hilum.

TYPE 5.

Habit.—Very early, spreading, very much open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Large (2·7 and 1·5×0·4) yellowish green ; 6 pairs of leaflets.
Flowers.—White with lilac colour on the veins only.
Pod.—Bold (1·6×0·7).
Seed.—Large, vinaceous buff, sparse cloudy mottling, grade, 1, occasional sky-grey speckling grade 1, but always with a speckle at the micropylar end of the hilum.

TYPE 6.

Habit.—Early, spreading, very much open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·2 and 1·1×0·4), dark-bluish-green ; 6 pairs of leaflets.
Flowers.—White.
Pod.—Small (1·1×0·5).
Seed.—Small, vinaceous pink, sparse cloudy mottling, grade 1, no speckling, pale yellow hilum.

TYPE 7.

Habit.—Very early, semi-erect, somewhat open, scanty branching.
Stem.—Green, angular and hairy.
Leaves.—Small (2·1 and 1·1×0·4), dark green ; 6 pairs of leaflets ; tendrils small.
Flowers.—White.
Pod.—Small (1·2×0·5).
Seed.—Intermediate, buff pink, heavy cloudy mottling, grade 3, occasional sky-grey speckling grade 1, pale yellow hilum.

TYPE 8.

Habit.—Very early, semi-erect ; somewhat open, with scanty branching.
Stem.—Green with red colour at the base, angular and hairy.
Leaves.—Large (2·8 and 1·6×0·4) yellowish green ; 5 pairs of leaflets.
Flowers.—Violet with a pinkish tinge.
Pod.—Bold (1·5×0·7).
Seed.—Large, pale pinkish buff ; heavy cloudy mottling, grade 3, and sparse sky-grey speckling grade 1 ; hilum pale yellow.

TYPE 9.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·3 and 1·5×0·5) yellowish green, 7 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Bold (1·5×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 10.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·4×0·5) light yellowish-green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 2.

Pod.—Bold (1·5×0·7.)

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 11.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·7 and 1·1×0·4) yellowish-green with red tinge at the margin of the leaflets and on the stipules ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 12.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, red colour at the base, angular and hairy.

Leaves.—Small (2·0 and 1·3×0·4), yellowish-green with reddish tinge on the margin of the leaflets and on the stipules ; 5 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Medium (1·3×0·7).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 13.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·3×0·5), yellowish-green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 14.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·4×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·4×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 15.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·4 and 1·5×0·5), yellowish-green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling. grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 16.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·8 and 1·5×0·5), yellowish-green, slight red tinge at the margin of the leaflets ; 5 pairs of leaflets.

Flowers.—Violet, grade 1.

Pod.—Medium (1·4×0·6).

Seed. Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky grey speckling, grade 1 with a prominent speckle at the micropylar end of the hilum.

TYPE 17.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·4×0·4), dull green ; 5 pairs of leaflets.

Flowers.—Violet, grade 1.

Pod.—Bold (1·5×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling, grade 1, with a prominent speckle at the micropylar end of the hilum.

TYPE 18.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·9 and 1·3×0·4), deep yellowish green ; 6 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Small (1·0×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 19.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·6 and 1·3×0·4), light yellowish green ; 6 pairs of leaflets.

Flowers.—Violet, grade 1.

Pod.—Bold (1·5×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 20.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·9 and 1·4×0·5), green with red tinge on the margins of leaflets and on the stipules ; 5 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Bold (1·6×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with prominent speckle at the micropylar end of the hilum.

TYPE 21.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·2 and 1·4×0·5), deep yellowish-green with slight red tinge at the margin of the leaflets and on the stipules ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 22.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (3·1 and 1·5×0·4), green with red tinge on the margin of the leaflets and on the stipules ; 5 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold (1·5×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 23.

Habit.—Medium in maturity, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·9 and 1·2×0·4), yellowish-green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 24.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·1×0·4), dull green ; 6 pairs of leaflets.

Flowers.—Violet, grade 2.

Pod.—Bold (1·5×0·6).

Seeds.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 25.

Habit.—Very early, erect, somewhat closed, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Large (3·4 and 1·3×0·4), light green; 5 pairs of leaflets. Tendrils small.

Flowers.—White.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling grade 3, medium sky-grey speckling grade 2, pale yellow hilum.

TYPE 26.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green angular and hairy.

Leaves.—Small (2·0 and 1·2×0·4), dark green; 6 pairs of leaflets. Tendrils small.

Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, pale yellow hilum.

TYPE 27.

Habit.—Early, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·1 and 1·2×0·5), light green; 6 pairs of leaflets. Tendrils small.

Flowers.—Violet grade 1.

Pod.—Medium (1·4×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, pale yellow hilum.

TYPE 28.

Habit.—Medium in maturity, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·9 and 1·0×0·3), yellowish-green with slight reddish tinge on the margin of the leaflets and on the stipules; 6 pairs of leaflets. Tendrils small.

Flowers.—Violet with a pinkish tinge.

Pod.—Small (1·1×0·5).

Seed.—Small, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, pale yellow hilum.

TYPE 29.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (2·8 and 1·5×0·5), yellowish green with slight red tinge on the margin of leaflets and on the stipules; 6 pairs of leaflets.

Flowers.—Violet with a light pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 30.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·3 and 1·5×0·5), yellowish green; 5 pairs of leaflets.

Flowers.—Violet grade 1, deeper than in any other case, both on the base of the standard as well as on the border of the wings.

Pod.—Bold (1·6×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 31.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small (1·9 and 1·2×0·4), dull-green; 5 pairs of leaflets. Tendrils small.

Flowers.—White.

Pod.—Medium (1·3×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 32.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base and red splashes on the branches, angular and hairy.

Leaves.—Medium (2·1 and 1·1×0·4), yellowish green. Red tinge on the margin of leaflets and on stipules ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 33.

Habit.—Early, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Medium (2·1 and 1·1×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 34.

Habit.—Medium in maturity, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·9 and 1·0×0·4), deep yellowish green with slight reddish tinge on the margin of the leaflets and on the stipules ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Small (1·2×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 35.

Habit.—Medium in maturity, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·6 and 1·0×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 36.

Habit.—Late, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·9 and 1·0×0·4), yellowish green ; 5 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 37.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·4 and 1·2×0·4), light green ; 6 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Small (1·2×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a prominent speckle at the micropylar end of the hilum.

TYPE 38.

Habit.—Medium in maturity, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (2·0 and 1·0×0·4), yellowish green ; 5 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 39.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (2·0 and 1·3×0·4), yellowish green with red tinge on the margin of leaflets and on stipules ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold (1·4×0·6).

Seed.—Small, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 40.

Habit.—Very late, trailing, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (2·1 and 1·0×0·3), yellowish green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Small (1·1×0·5).

Seed.—Small, pale pinkish buff, heavy cloudy mottling, grade 3, medium sky-grey speckling grade 2, with a speckle at the micropylar end of the hilum.

TYPE 41.

Habit.—Very early, spreading, very much open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·4×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet with a pinkish tinge.

Pod.—Bold (1·6×0·7).

Seed.—Large, pale pinkish buff, heavy cloudy mottling, grade 3, heavy sky-grey speckling grade 3, with a very prominent speckle at the micropylar end of the hilum.

TYPE 42.

Habit.—Early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·5 and 1·5×0·4), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, heavy cloudy mottling, grade 3, heavy sky-grey speckling grade 3, with a prominent speckle at the micropylar end of the hilum.

TYPE 43.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Medium (2·2 and 1·3×0·4), dull green; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Medium (1·3×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 44.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·0 and 1·1×0·4), green ; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Small (1·1×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 45.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·1 and 1·1×0·4), dark green ; 6 pairs of leaflets ; tendrils small.

Flowers.—White.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 46.

Habit.—Early, spreading, very much open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·4 and 1·1×0·4), dark green ; 7 pairs of leaflets.
Flowers.—White.
Pod.—Small (1·1×0·5).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 47.

Habit.—Early, trailing, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·2 and 1·2×0·4), dark-bluish-green ; 7 pairs of leaflets.
Flowers.—White.
Pod.—Small (1·1×0·5).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 48.

Habit.—Very early, spreading, very much open, profuse branching.
Stem.—Green with red colour at the base, angular and hairy.
Leaves.—Medium (2·1 and 1·5×0·5), yellowish green with a slight reddish tinge on the margin of the leaflets and on the stipules ; 5 pairs of leaflets.
Flowers.—Violet with a pinkish tinge.
Pod.—Bold (1·4×0·7).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 49.

Habit.—Early, semi-erect, open somewhat, profuse branching.
Stem.—Green with red colour at the base, angular and hairy.
Leaves.—Small (2·0 and 1·1×0·4) yellowish green with slight reddish tinge on the margin of the leaflets and on the stipules ; 7 pairs of leaflets.
Flowers.—Violet with a light pinkish tinge.
Pod.—Small (1·2×0·6).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 50.

Habit.—Early, semi-erect, somewhat open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·2 and 1·3×0·6), dull green; 6 pairs of leaflets ; tendrils small.
Flowers.—Violet with a pinkish tinge.

Pod.—Small (1·1×0·6).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 51.

Habit.—Medium in maturity, semi-erect, somewhat open, profuse branching.

Stem.—Green with red colour at the base.

Leaves.—Small (2·1 and 0·9×0·3), deep yellowish green with reddish tinge on the margin of the leaflets and on the stipules ; 7 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Small (1·2×0·6).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 52.

Habit.—Late, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Large (3·0 and 1·1×0·4), dark green ; 6 pairs of leaflets.

Flowers.—Violet grade 1.

Pod.—Medium (1·3×0·6).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 53.

Habit.—Very late, semi-erect, somewhat open, bushy, profuse branching.

Stem.—Green with red colour at the base, angular and hairy.

Leaves.—Small (1·6 and 1·0×0·3), yellowish green ; 6 pairs of leaflets.

Flowers.—Violet grade 2.

Pod.—Small (1·2×0·6).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with pale yellow hilum.

TYPE 54.

Habit.—Very early, semi-erect, somewhat open, profuse branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·0 and 1·2×0·4), light green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 2.

Pod.—Small (1·2×0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 55.

Habit.—Very early, semi-erect, somewhat open, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·1 and 1·0×0·4), dark green ; 6 pairs of leaflets ; tendrils small.

Flowers.—White.
Pod.—Small (1·1×0·5).
Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 56.

Habit.—Very early, spreading, very much open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·4 and 1·2×0·4), green; 6 pairs of leaflets; tendrils small.
Flowers.—White.
Pod.—Small (1·2×0·5).
Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 57.

Habit.—Early, spreading, very much open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·3 and 1·1×0·4), green; 6 pairs of leaflets; tendrils small.
Flowers.—White.
Pod.—Small (1·2×0·6).
Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 58.

Habit.—Early, semi-erect, somewhat open, profuse branching.
Stem.—Green with red colour at the base, angular and hairy.
Leaves.—Small (2·0 and 0·9×0·3), yellowish green; 6 pairs of leaflets; tendrils small.
Flowers.—Violet with a pinkish tinge.
Pod.—Small (1·1×0·5).
Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, pale yellow hilum.

TYPE 59.

Habit.—Early, erect, somewhat closed, scanty branching.
Stem.—Green with red colour at the base, angular and hairy.
Leaves.—Medium (2·2 and 1·1×0·4), yellowish green; 5 pairs of leaflets.
Flowers.—Violet grade 1.
Pod.—Bold (1·4×0·6).
Seed.—Large, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 60.

Habit.—Early, semi-erect somewhat open, scanty branching.
Stem.—Green, angular and hairy.

Leaves.—Medium (2·7 and 1·4×0·5), dull green, 5 pairs of leaflets.
Flowers.—Violet grade 2.
Pod.—Medium (1·4×0·6).
Seed.—Large, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 61.

Habit.—Very early, erect, somewhat closed, scanty branching.
Stem.—Green, angular and hairy.
Leaves.—Very large (3·8 and 1·3×0·4) light green; 6 pairs of leaflets; tendrils small.
Flowers.—White.
Pod.—Small (1·2×0·5).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 62.

Habit.—Early, spreading, very much open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·3 and 1·1×0·5), green; 7 pairs of leaflets.
Flowers.—White.
Pod.—Small (1·2×0·6).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 63.

Habit.—Early, trailing, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·1 and 1·1×0·5), dark green; 7 pairs of leaflets.
Flowers.—White.
Pod.—Small (1·1×0·6).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 64.

Habit.—Very early, semi-erect, somewhat open, profuse branching.
Stem.—Green, angular and hairy.
Leaves.—Medium (2·6 and 1·5×0·5), light yellowish green; 6 pairs of leaflets.
Flowers.—Violet grade 1.
Pod.—Bold (1·5×0·7).
Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a prominent speckle at the micropylar end of the hilum.

TYPE 65.

Habit.—Late, spreading, very much open, profuse branching.

Stem.—Green with red colour at the base, angular, and hairy.

Leaves.—Medium (2·5 and 1·1 × 0·4), yellowish green ; 6 pairs of leaflets ; tendrils small.

Flowers.—Violet grade 1.

Pod.—Bold (1·4 × 0·5).

Seed.—Intermediate, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

TYPE 66.

Habit.—Very early, spreading, open very much, scanty branching.

Stem.—Green, angular and hairy.

Leaves.—Small (2·8 and 1·1 × 0·4), dark green ; 5 pairs of leaflets.

Flowers.—White.

Pod.—Small (1·1 × 0·5).

Seed.—Small, pale pinkish buff, medium cloudy mottling, grade 2, sparse sky-grey speckling grade 1, with a speckle at the micropylar end of the hilum.

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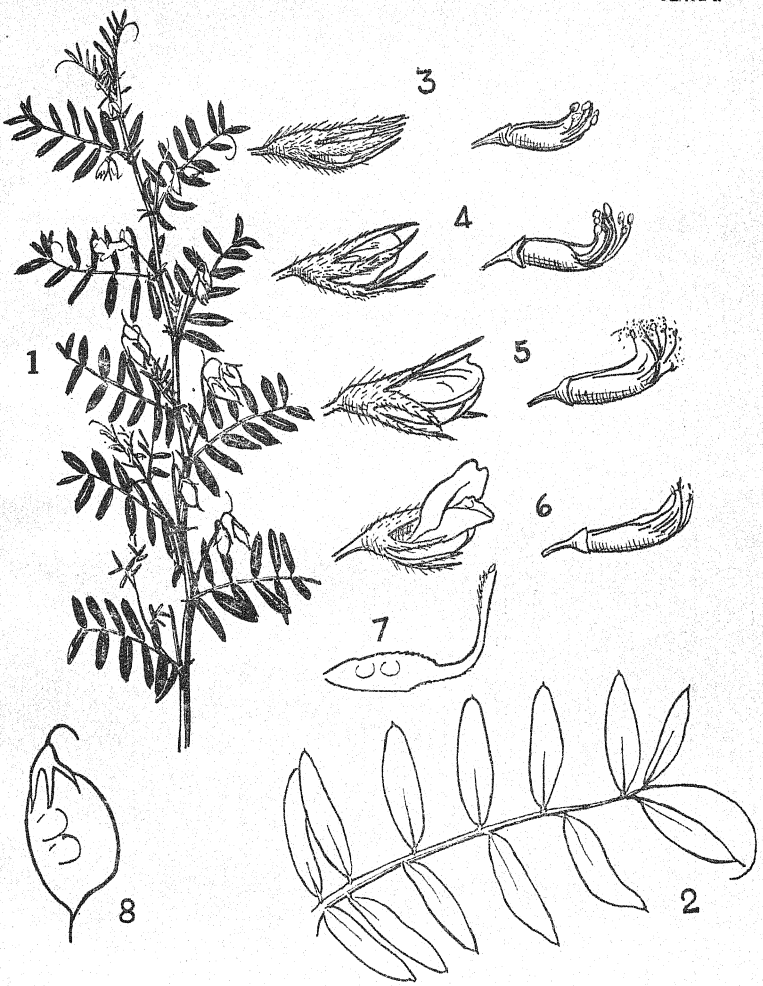
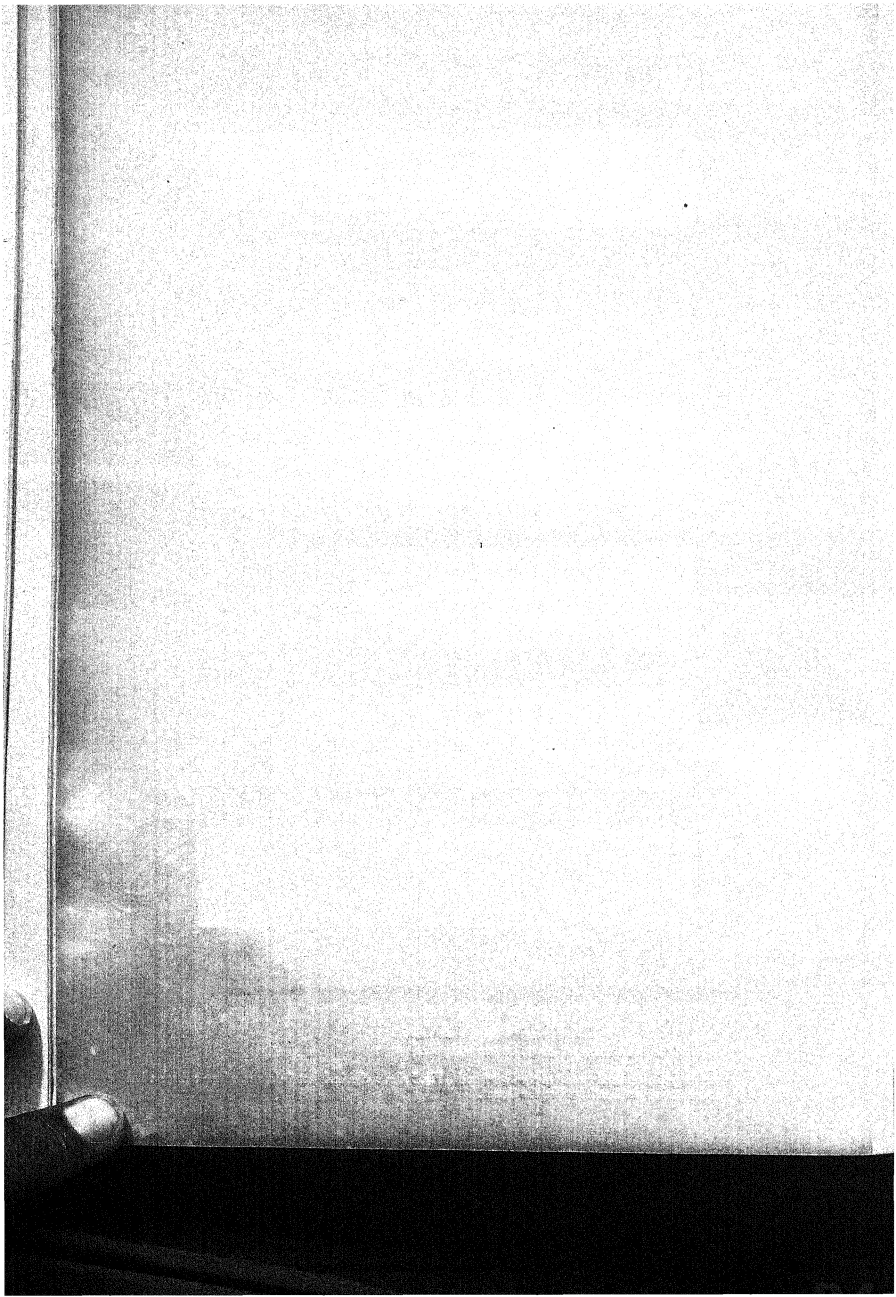
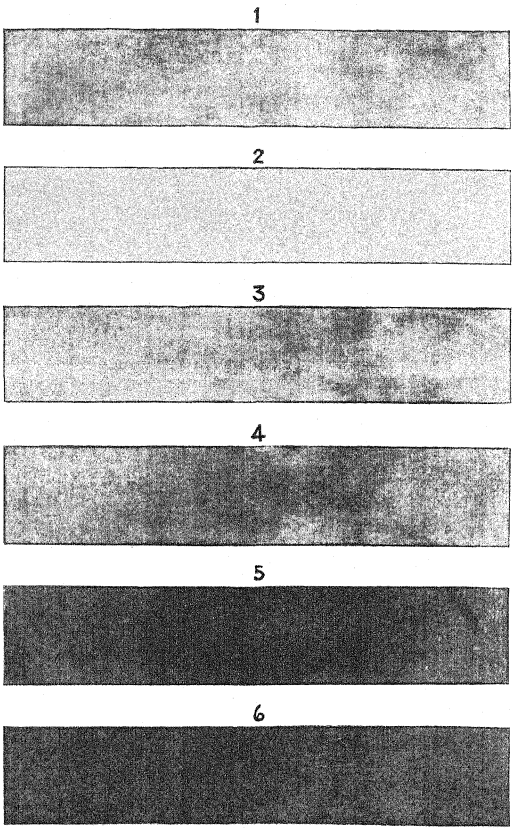


Morphological details in Lentils.

Fig. 1. Branch showing the arrangement of leaves, flowers and pods.
Fig. 2. Leaf.
Figs. 3-8. Different stages in the development of the flower bud. Fig. 5 shows the bud just before opening—a stage when the pollen grains burst and fertilise the flower.





Tints of foliage colour when seen in mass.

1, Dull (light bluish) green; 2, Light yellowish green; 3, Yellowish green; 4, Green; 5, Dark green; 6, Dark bluish green.

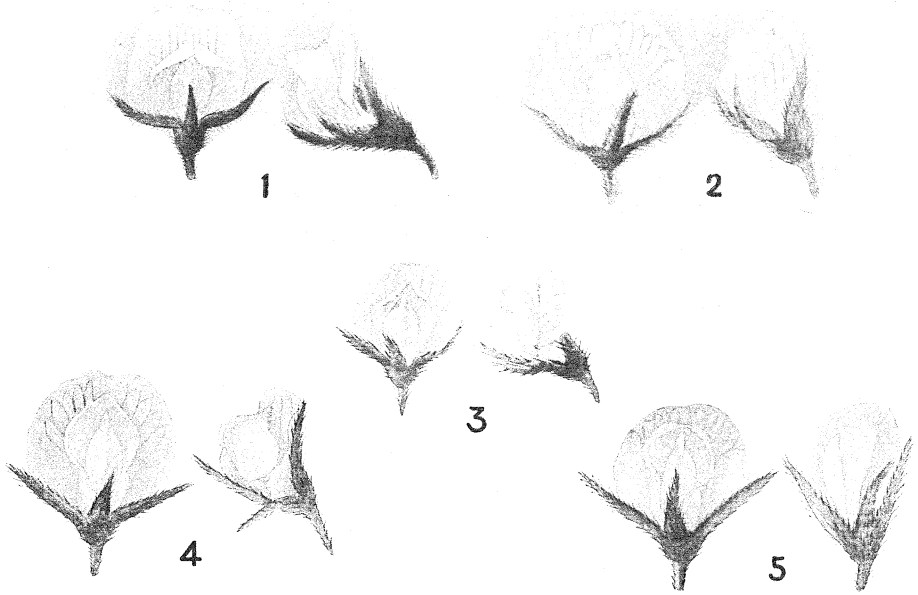
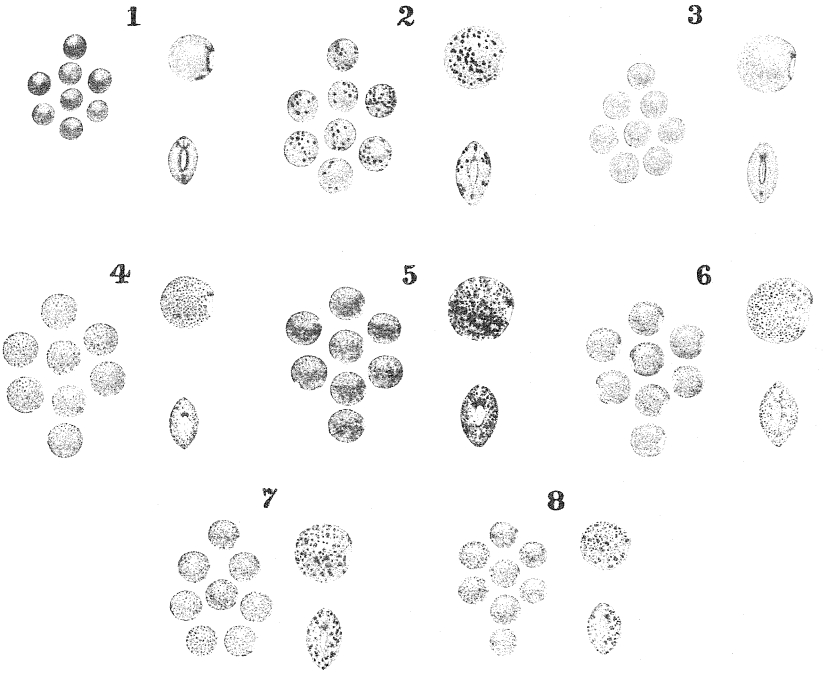


PLATE III.

The range in flower colour.

1, White—Type 6; 2, White with lilac colour on the veins—Type 2; 3, Pink—Type 1; 4, Violet with a pinkish tinge—Type 8; 5, Violet, Grade I—Type 9.



Seed coat colour and markings.
1, Type 1; 2, Type 2; 3, Type 5; 4, Type 17; 5, Type 41; 6, Type 19; 7, Type 33; 8, Type 58.

PLATE IV.

PYTHIUM APHANIDERMATUM (EDS.) FITZ. ON *OPUNTIA DILLENII*, HAW.

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In the course of certain investigations with *Opuntia Dillenii*, a number of plants were being grown in pots and it was found that many of them had died due to the rotting of the cladodes during the rainy months in October 1925. They had been raised by planting young rooted cladodes dug out from the neighbourhood. These established well and were coming up splendidly, when suddenly all of them began to show symptoms of rotting. The rotting was found to extend either from the ground level upwards or from the top of the cladodes downwards, obviously depending on the portion initially infected. The affected portions were of a dirty brown discoloration with an advancing margin of a dull green colour having a water-soaked appearance and of about half a centimetre in width. In the course of a week the plants had rotted completely, being reduced to a soft watery pulp, and in ten days nothing was left in the pots except a few vascular strands.

When bits of plant in the early stages of infection were removed and incubated in moist chambers, a good fluffy growth of fungus mycelium developed enveloping the bits in a cottony mass. From these the fungus was brought into pure culture and further study revealed the organism to be *Pythium aphanidermatum*.

Pythium aphanidermatum has a wide distribution, being associated with diseases of roots and seedlings of a number of economic plants and causing fruit rots of some field and truck crops. Butler [1] noted the fungus to be parasitic on the roots and rhizomes of *Zingiber officinale* and roots of castor and recorded it as a variety of *Pythium gracile*. Edson [2] isolated the fungus from diseased beet and radish seedlings in America and described it under a new genus *Rheosporangium aphanidermatum*. Later Subramaniam [3] investigated the rhizome rot of ginger in India in greater detail and described the fungus causing the disease as *Pythium Butleri*. Be-

[1] Butler, E. J. The genus Pythium and some Chytridiaceæ. *Mem. Dept. Agri. India, Bot. Series*, Vol. 1, No. 5.

[2] Edson, H. A. *Rheosporangium aphanidermatum*, a new genus and species of fungus parasitic on sugar beets and radishes. *Jour. Agri. Res.*, 4, 279-292.

[3] Subramaniam, L. S. A Pythium disease of ginger, tobacco and papaya. *Mem. Dept. Agri. India, Bot. Series*, Vol 10, 181-194.

sides ginger he found that the same fungus was parasitic on tobacco, papayas, chillies and castor seedlings. In Hawaii, Carpenter[1] noticed that a similar fungus affected the roots of sugarcane causing the "Lahaina" disease. He found that the fungus resembled *P. Butleri* and at the same time recognized the resemblance and identity of the American form described by Edson and the Indian one by Subramaniam and preferred to name his fungus as *Pythium Butleri*. Fitzpatrick[2] after studying the two forms (American and Indian) came to the conclusion that the two were identical and renamed the fungus as *Pythium aphanidermatum*, retaining in this new combination the specific name of Edson by virtue of priority. As the causal agent of the 'cottony leak' of cucumbers, squash[3] and fruits of egg plant[4] which are badly damaged sometimes in the fields and more often during transit, it has been recorded by Drechsler in the United States. The same writer has described a cabbage rot caused by this fungus. Harter and Whitney[5] mention that *P. aphanidermatum* is very commonly present on beans in transit in Florida during the warmer months of the shipping season and produces a 'nesting' of the fruits. From Illinois and Wisconsin, Johann, Herbert and Dickson[6] report a seedling blight and root rot of dent corn caused by this organism. Mitra[7] and Mitra and Subramaniam[8] have investigated the fruit rots of some cucurbitaceous plants caused by the same fungus in India. Shaw[9] has isolated this organism from diseased plants of *Amaranthus gangeticus*.

In *Opuntia* the mycelium of the fungus invades all the tissues of the host, being mostly intra-cellular and more common in the parenchymatous portions of the tissues. The hyphæ are constricted just where they pass through the cell walls, again regaining the normal size on emergence on the other side. When the infected plants are covered with a bell jar, the hyphæ grow out of the tissues forming a white cottony growth over the cladodes (Plate III, 1.) The hyphæ come out either through the stomata or piercing through the epidermal cell-wall. Just before piercing through the outer epidermal wall, the hypha swells into a globular structure. The portion that passes through the wall is constricted. On emergence it is again swollen, gradually assuming the normal thickness as it

[1] Carpenter, C. W. Morphological studies of the Pythium-like fungi associated with root rot in Hawaii. *Bull. Expt. Stn. Hawaii Sugar Planters Association, Bot. Series*, 3, 59-65.

[2] Fitzpatrick, H. N. Generic concepts in the Pythiaceae and Blastocladiaceae. *Mycologia*, 15, 166-173.

[3] Drechsler, C. The cottony leak of cucumbers caused by *Pythium aphanidermatum*. *Jour. Agri. Res.*, Vol., 1035-1042.

[4] Drechsler, C. The cottony leak of egg plant fruit caused by *P. aphanidermatum*. *Phytopathology*, Vol. 16, 47-50.

[5] Harter, L. L., and Whitney, W. A. A transit disease of snap beans caused by *P. aphanidermatum*. *Jour. Agri. Res.*, Vol. 34, 443-448.

[6] Johann, H., Herbert, J. R., and Dickson, J. G. A Pythium seedling blight and root rot of dent corn. *Abs.* in *Phytopathology*, Vol. 16, 85.

[7] Mitra, M. Fruit rot disease of cultivated Cucurbitaceae caused by *P. aphanidermatum* (Eds.) Fitz. *Abs. in Proc.* 14th *Ind. Sc. Congress, Lahore* 1927, Botany Section, p. 213.

[8] Mitra M., and Subramaniam, L. S. Fruit rot of some cucurbitaceous fruits caused by *P. aphanidermatum*. *Mem. Dept. Agri. India, Bot. Series*, Vol. XV, No. 3.

[9] List of fungi received by the Imperial Bureau of Mycology, London, List 1.

elongates (Plate I, 3). Besides infecting the tissues of the cladodes, the hyphæ are present inside the hairs found round the spines. The hyphæ grow inside the hairs piercing through the cross walls, being constricted at the point of passage from cell to cell and finally growing out through a side or the tip (Plate I, 4).

The fungus was easily brought into pure culture from diseased *Opuntia* and numerous infection experiments were carried out to determine the range of parasitism of the fungus and to find out if the strain from *Opuntia* is capable of infecting the numerous hosts on which *P. aphanidermatum* has been recorded. Besides *Opuntia*, inoculations were made on the known hosts of *P. aphanidermatum* and a few other plants allied to them. The experiments were in all cases conducted on young potted plants and after inoculating the parts they were covered over with bell jars in order to keep up a humid atmosphere inside. The cucurbitaceous and solanaceous fruits and cabbage were kept after washing them with mercuric chloride solution and sterilized water, inside sterilized moist chambers and then inoculated. In all the experiments, controls—under similar conditions and treated similarly with the exception of the inoculum—were kept and these remained always healthy and unaffected.

The following table gives the results of the infection experiments.

Plant	Part inoculated	Methods of inoculation	Number inoculated	Number infected	Remarks
Opuntia Dillenii .	Cladode .	Mycelium and sporangia placed in drops of water on the surface.	8	8	All the plants rotted down completely.
Ditto .	Young buds . .	Ditto .	6	6	From the buds the infection proceeded to the main cladode and down the plant.
Ditto .	Hairs round the spines.	Ditto .	4 groups	4 groups	From these infection spread to the cladodes.
Ditto .	Flowers . .	Ditto inside the flowers (In nature.)	6	6	The flowers rotted and through their base infection spread to the cladode.
Euphorbia antiquorum.	Cladode . .	Mycelium and sporangia on the surface of the cladode.	5	5	The cladode rotted down.
Amarantus gangeticus.	Base of stem . .	Mycelium and sporangia on the surface.	5	5	The plants wilted and the base of the shoots rotted.
Castor seedlings (One month old).	Ditto .	Ditto .	6	6	The collar region rotted and the rotting spread to the other portions.
Ginger . . .	Ditto .	Ditto .	4	4	The base of the shoots became soft and rotted.
Tomato seedlings (one month old).	Ditto .	Ditto .	6	6	Ditto

Plant	Part inoculated	Methods of inoculation	Number inoculated	Number infected	Remarks
Tomato seedlings (one month old).	Terminal bud	Mycelium and sporangia on the surface.	4	4	The rotting gradually extended down and finally the plants died.
Tomato	Fruits	Ditto wounded	4	4	The fruits rotted and a fluffy growth of mycelium formed on them.
Ditto	Ditto	Ditto unwounded.	6	6	Ditto
Tobacco seedlings (one month old).	Leaves	Mycelium and sporangia on the surface.	6	6	Spots formed on the leaves and gradually involved the whole plant in a wet rot.
Capsicum seedlings	Base of stem	Ditto	3	3	The plants wilted and bent over at the rotten base.
Ditto	Terminal bud	Ditto	3	3	The buds rotted and finally the whole plants.
Datura seedlings	Leaves and terminal buds.	Ditto	4	4	Spots formed on the leaves and the buds rotted. Rot extended downwards.
Solanum nigrum seedlings.	Ditto	Ditto	6	6	Ditto
Solanum melongena seedlings.	Ditto	Ditto	4	3	Spots formed on the leaves and the buds rotted.
Solanum melongena	Fruits	Ditto wounded	4	4	Spots formed round the inoculated portions and the fruits rotted.
Solanum tuberosum seedlings.	Leaves and buds	Mycelium and sporangia.	6	6	Spots formed on the leaves and the buds rotted.
Ditto	Base of stem	Ditto	3	3	Shoots rotted.
Solanum tuberosum	Tubers	Ditto on wounded surface.	4	4	Tubers rotted.
Petunia seedlings	Base of stem	Mycelium and sporangia on the surface.	4	3	Shoots rotted at the base.
Physalis seedlings	Ditto	Mycelium and sporangia placed on the surface.	4	4	Ditto
Papaya seedlings (1½ months' old).	Ditto	Ditto	6	6	All the plants rotted at the base.
Papaya (6 months' old).	Ditto	Ditto wounded	2	2	Ditto
Papaya (big tree)	Ditto	Ditto	2	..	Did not take infection.
Papaya	Raw fruits	Ditto	4	..	Ditto
Basella rubra seedlings.	Leaves and base of stem.	Mycelium and sporangia on the surface.	4	4	Spots formed on the leaves and the plants rotted.
Beet root seedlings	Leaves and buds	Ditto	4	4	Ditto
Sugarcane seedlings	Roots	Mycelium and sporangia placed in the soil round the roots.	8 sets	8 sets	The roots were discoloured and rotted.

Plant	Part inoculated	Methods of inoculation	Number inoculated	Number infected	Remarks
Cabbage	Cut head	Mycelium on the cut surface.	2	2	The whole head rotted.
Amorphophallus	Mature leaves	Mycelium and sporangia on the surface.	4	4	Formed small spots which did not progress.
Ditto	Young leaves	Ditto	3	3	Whole leaves rotted.
Colocasia	Leaves	Ditto	4	4	Spots formed on the leaves.
Luffa acutangula	Fruits	Ditto	3	3	Fruits rotted and a cottony growth of mycelium formed over the fruits.
Momordoica	Ditto	Ditto	4	4	Ditto
Cucumis sativus	Ditto	Ditto	4	4	Ditto
Trichosanthes	Ditto	Ditto	3	3	From the fruits the infection spread to the vine (inoculated in nature).
Maize seedlings	Base of stem	Ditto	6	6	All the seedlings rotted.

Pythium aphanidermatum exhibits an extensive host range, being capable of infecting plants belonging to widely separated families. Many members of the Cucurbitaceae and the Solanaceae are liable to be parasitised by the fungus. The infection of the plants and the consequent wilting are quicker during the seedling stage when they are soft and juicy. In many instances infection takes place at the collar region or through the roots, the base of the stem rots and the plants fall over. On physalis, tomato, castor and some others, the fungus is capable of affecting the terminal buds and the rotting proceeds downwards finally involving the whole plant. Young buds and leaves are also liable to be infected. On the leaves dull green water-soaked spots are formed which gradually increase in size and in course of time the entire leaf rots. Fruits of cucurbitaceous plants and tomatoes are readily infected. On fruits of egg plant, however, previous wounding is necessary for successful infection. Fruits of *Trichosanthes anguina* on a vine growing over a trellis were inoculated and the infection spread from the fruits which rotted to the vines also resulting in the wilting of the latter. In nature it has been observed that the infection of the fruits is more common on those which lie touching the soil than on those higher up, indicating that the infection originates from the soil. Wounded fruits take up the infection much more readily than unwounded ones. It can be broadly stated that, given proper conditions of moisture and warmth, the fungus is capable of infecting the succulent portions of many plants especially in the seedling stage.

On *Opuntia*, inoculations were made at different portions of the plant to find out the parts capable of being infected. The inocula were placed on the surface of the mature cladodes, young cladodes, on the hairs surrounding the spines, tender buds and flowers. Infection proceeded from all these portions, the mature cla-

dodes alone being less readily infected than the others which readily succumbed to the fungus. Once the infection has started, it proceeds through the tissues to the other portions till finally the whole plant is reduced to a pulpy mass.

Besides experimenting with *Opuntia* plants growing in pots, inoculations were carried out in the open field on clumps of this plant thriving under natural conditions. Infections made during the rainy days or when the weather was cloudy and humid were quite successful. The inocula consisting of the mycelium and sporangia of the fungus were placed on the cladodes and covered over with a thin layer of moistened cotton wool. The evidences of infection were visible even on the third day and if the weather continued to be humid and cloudy, a rapid spread occurred involving the whole plant in the course of a week. On the other hand, the progress of infection was arrested if bright weather intervened, it being confined to one or two joints. In several cases a whitish mucilaginous fluid was observed to exude from the joints of the infected cladodes. Several attempts to infect the plants during sunny days with comparatively dry weather were not successful. The fungus was repeatedly re-isolated from the artificially infected plants, thus proving its pathogenicity.

Pythium aphanidermatum grows luxuriantly on a number of artificial media. It was cultivated on several synthetic media and others containing plant extracts. Sterilized plant tissues also were employed. In many of the cultures a white dense cottony aerial mycelial growth develops which often fills the whole lumen of the tubes. After remaining like this for some days, the whole growth subsides being matted down on the surface of the slant producing the appearance of a wet and sodden cotton-wool-like layer. The growth of the fungus is very quick on many of the media, the whole slant being covered over in the course of 4 to 5 days. The following table gives the relative luxuriance of the growth on the several media employed and the nature of the reproductive structures formed on them. The cultures compared were of the same age, being a week old.

Agar media arranged in the order of the luxuriance of growth.

No.	Kind of medium	Nature of growth	Reproductive structures formed	Remarks
1	Papaya fruit extract agar	A very luxuriant white cottony growth filling up the whole lumen of the tube	Numerous lobulate sporangia and innumerable oospores formed.	The best media for the growth of the fungus.
2	Quaker oats agar	Ditto	Ditto	
3	French bean agar	A good luxuriant white fluffy growth.	Numerous oospores and lobulate sporangia formed.	A good medium for the growth of the fungus.
4	Wheat agar	A good white fluffy growth not so dense as in the former.	Oospores formed in plenty. Lobulate sporangia produced.	Both are equally good.
5	Corn meal agar	A good white fluffy growth as in wheat agar.	Ditto	

No.	Kind of medium	Nature of growth	Reproductive structures formed	Remarks
6	Cotton seed extract agar.	A good white fluffy growth is developed.	Oospores and lobulate sporangia formed.	
7	Rice agar . .	Ditto .	Oospores not so numerous as in 1 to 5 agars. Lobulate sporangia and stout curved structures formed.	The growth on these two was almost alike in luxuriance.
8	Potato dextrose agar .	A fluffy aerial growth is formed but not so dense as in the ones above.	Oospores few. Lobulate sporangia also few in number. A number of club shaped and falcate structures formed.	
9	Amaranthus stem extract agar.	A fluffy aerial growth develops.	Oospores not many in number. Lobulate sporangia and the club shaped or falcate structures present.	
10	Glucose agar . .	Ditto .	Oospores and lobulate sporangia absent or very rarely seen. The curved thickened structures present.	
11	Ginger-rhizome-extract agar.	The growth of the fungus is mostly submerged and poor.	Oospores and lobulate sporangia absent or very rarely formed.	
12	Beet-root-extract agar .	Growth mostly submerged or slightly aerial.	Lobulate sporangia are formed in numbers. Oospores not many.	
14	Nutrient agar . .	Growth submerged .	Oospores and lobulate sporangia absent. Curved thick structures present.	
15	Agar agar . . .	Submerged growth .	Oospores and lobulate sporangia formed.	
16	Congo red agar . .	Submerged and very slow growth.	Lobulate sporangia absent. Oospores rare.	The colour of the medium is not changed.

The growth of the fungus on sterilized plant tissues was as follows :—

Plant tissues used	Nature of growth	Remarks
Papaya fruit	Dense white fluffy growth filling up the whole tube.	Numerous lobulate sporangia and oospores formed.
Beet-root tuber . . .	Dense white luxuriant growth of mycelium.	Oospores and lobulate sporangia formed.
Potato tuber	Dense white fluffy growth filling up the tube.	
Ginger rhizome . . .	A white aerial mycelium not dense.	Oospores and sporangia few.
Opuntia cladodes . . .	White aerial growth . .	Lobulate sporangia and oospores numerous.
Amaranthus stem and leaves .	Ditto .	Ditto
Dolichos lablab fruits . .	White aerial mycelium better than in ginger.	Oospores and lobulate sporangia formed.

The bits of the plants were placed in Roux tubes with a small quantity of water at the bottom and then autoclaved. In the cultures on potato, papaya and beet root, a dense white growth resulted but the mycelium matted down a week later and formed a wet mass over the bits. The cultures were examined after 5 days growth.

Effect of reaction of the medium on the growth of the fungus. The fungus was grown on French bean agar of varying Fuller's scale to determine the effect of the reaction of the medium on the growth of the fungus. Three tubes of the medium of each of the reactions were inoculated with the fungus, and growths were noted at the end of 10 days. The experiment was repeated again and the results confirmed.

Reaction	Nature of growth	Remarks
—10	Very good luxuriant fluffy growth	Numerous oospores formed.
—5	Ditto	Ditto
Neutral	Equally good growth	Ditto
+5	Same luxuriance as in others	Ditto
+10	Equally luxuriant	Ditto
+15	Fluffy growth not so luxuriant as in +10 . . .	Oospores formed, medium was not solid.
+20	Poor growth	Medium liquid.
+25	Very little growth	Medium liquid.

A luxuriant growth of the fungus is noticed on the media whose reactions vary from—10 to+10, there being no difference between them as regards the general appearance of the growth. But as the acidity increases above+10, there is a diminution in growth and in + 25 there is very little growth. The fungus apparently tolerates a certain amount of acid or alkali in the medium.

Morphology of the fungus.

The mycelium of the fungus is much branched and is coenocytic when young, being full of granular protoplasm. In agar and water cultures the contents often exhibit a streaming movement first in one direction followed by a reversal after sometime. With age septa begin to appear in the hyphæ (Plate I, 1). Often in cultures on papaya fruits dense masses formed of intricately coiled hyphal branches are noticed (Plate I, 2).

Sporangia are formed both on solid agar media and in water cultures but are more numerous in the latter. These are of the characteristic type composed of swollen digitately branched structures. The germination of the sporangia and the formation of zoospores have been fully described by the previous workers and so are not detailed here (Plate I, 7 and 8 ; Plate II, 1-3a.)

On some media — as amaranthus extract, potato dextrose, and glucose agars — certain club shaped or thick and falcate structures develop. These differ from the normal sporangia and do not much resemble the antheridia. When placed in water, they were found to put out germ tubes which develop into hyphæ (Plate II, 4.) On account of this behaviour, it must be inferred that they are structures capable of functioning as conidia when placed under certain conditions. Carpenter [1] has noticed similar structures in *Pythium Butleri*, and considers them to be functioning as spores. Braun [2] working with *Pythium debaryanum* noticed " clavate sickle shaped bodies in plate cultures and in the interface of agar and glass," and suggests that they may be of an " appressorial nature."

Sexual reproduction is abundant and innumerable oospores are formed in agar media and water cultures 3 days' old. The development of the antheridia and oogonia and the formation of the oospores have been worked out in detail by Edson and other writers. The antheridia are terminal or intercalary and short and cylindric. The oogonia are round and smooth and measure on an average 26·3 μ in diameter (the limits being 18 and 30·6 μ). The oospores are round and thickwalled with a mean diameter of 20·2 μ, the maximum being 23·4 μ and the minimum 14·4 μ. They lie within the presistent oogonia which they do not completely fill (Plate II, 5, 6, 7 ; Plate III, 2, 3.) The ratio between the sizes of the oospores and oogonia varies from 1·16 to 1·46, the greatest number having a ratio between 1·26 and 1·30.

The oospore germinates when placed in water with the production of a germ tube. The oospore wall becomes thinner. From one side a germ tube originates which grows out piercing through the oogonial wall. The germ tube is either simple and grows out into a long hypha which later on branches or the branching takes place soon after it emerges out of the oogonial wall (Plate II, 8 ; Plate III, 4).

Comparative studies of *Pythium aphanidermatum* and *P. Butleri* were made to determine the affinities of the two organisms. For this purpose cultures of the latter fungus isolated from papayas were obtained from Pusa through the kind courtesy of Dr. McRae, Imperial Mycologist, in the year 1926. The two fungi were grown side by side on French bean, quaker oats, corn meal and papaya fruit-extract agars and no difference could be made out between the two either in the

[1] *Loc. cit.*

[2] Braun, H. Comparative studies of *Pythium debaryanum* and two related species from Geranium. *Jour. Agri. Res.*, Vol, 30, 1043-1062.

general appearance of the growths or in the formation of the reproductive structures.

Inoculations were carried out with both the fungi on seedlings of papaya, *Opuntia*, tomato, *Euphorbia antiquorum* and amaranthus. In both the series all the infections were successful, both the organisms being equally virulent on all the hosts. On grown up papaya plants (6 months old) however, *Pythium Butleri* was able to produce symptoms of rot earlier than *Pythium aphanidermatum*, while on plants 4 years old the latter was not able to cause the foot rot. The parasitism of *P. Butleri* on old papaya trees was the only point of difference between the two fungi that could be made out from infection experiments.

Two hundred each of the oospores and the oogonia of the two fungi were measured separately and the following table represents the measurements in microns.

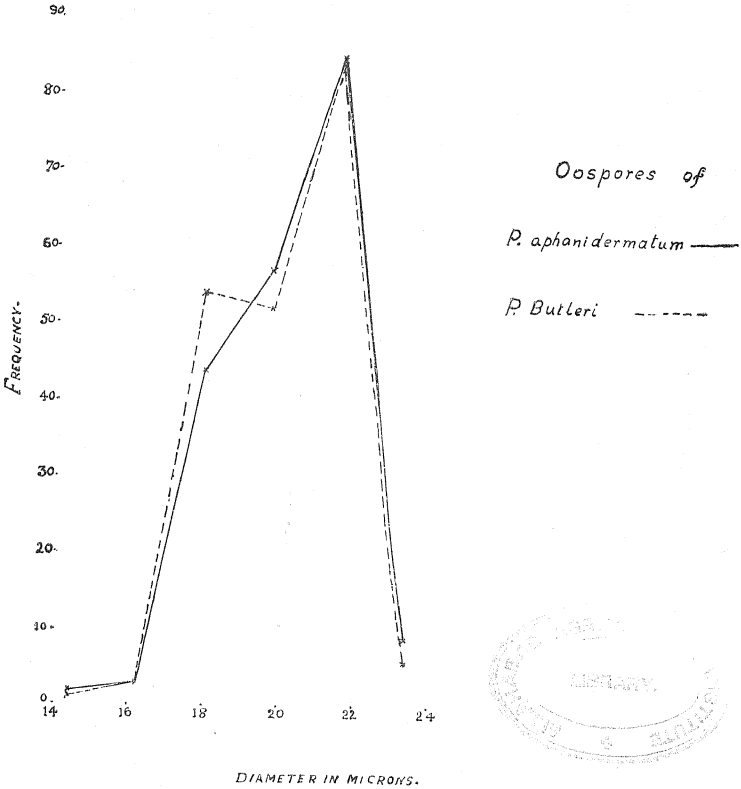
	Oospores				Oogonia			
	Max.	Min.	Mean	Median	Max.	Min.	Mean	Median
P. aphanidermatum .	23·4	14·4	20·2	21·6	30·6	18	26·3	25·2
P. Butleri . . .	23·4	14·4	20·1	21·6	28·8	18	24·6	25·2

The measurements of the oospores and oogonia of the two fungi are represented in charts 1 and 2.

No difference could be detected in the sizes of the oospores of the two fungi. The oogonia alone show slight variation in the maximum and mean but agree in the minimum and median measurements.

From a consideration of the various points on which they were compared, it is found that the two fungi resemble each other very closely and can be said to be identical. In the infection of old papaya plants they exhibit a difference and there is a slight variation between the sizes of the oogonia. This alone is not sufficient to maintain a specific differentiation especially when the organisms exhibit such striking similarities in other respects. Hence *P. Butleri* can be put down only as a strain of *P. aphanidermatum*, being more destructive on papayas. Mitra and Subramaniam, whose publication came out as this paper was being completed, also conclude that *P. Butleri* is only a strain of *P. aphanidermatum*.

The writer is indebted to Mr. S. Sundararaman, the Government Mycologist, Coimbatore, for advice and suggestions in carrying out this investigation which was done while the writer was an assistant in his section.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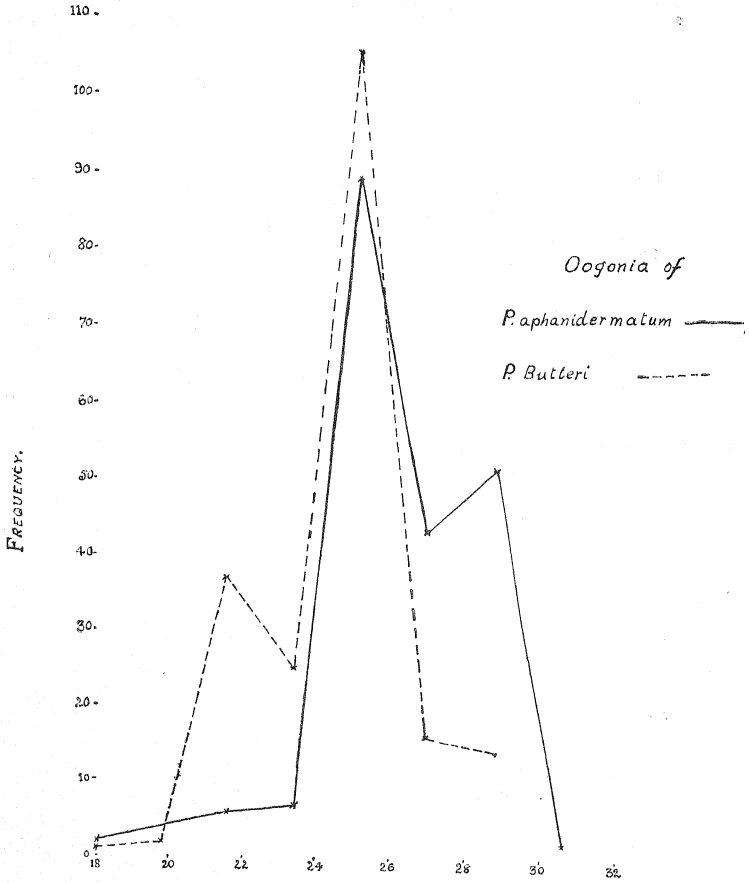
DIAMETER IN MICRONS.
Oospores of
P. aphanidermatum
P. Butleri

Chart 1.


110
100
90
80
70
60
50
40
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20
10
0
FREQUENCY.
18
20
22
24
26
28
30
32
Oogonia of
P. aphanidermatum
P. Butleri
DIAMETER IN MICRONS.

Chart 2.

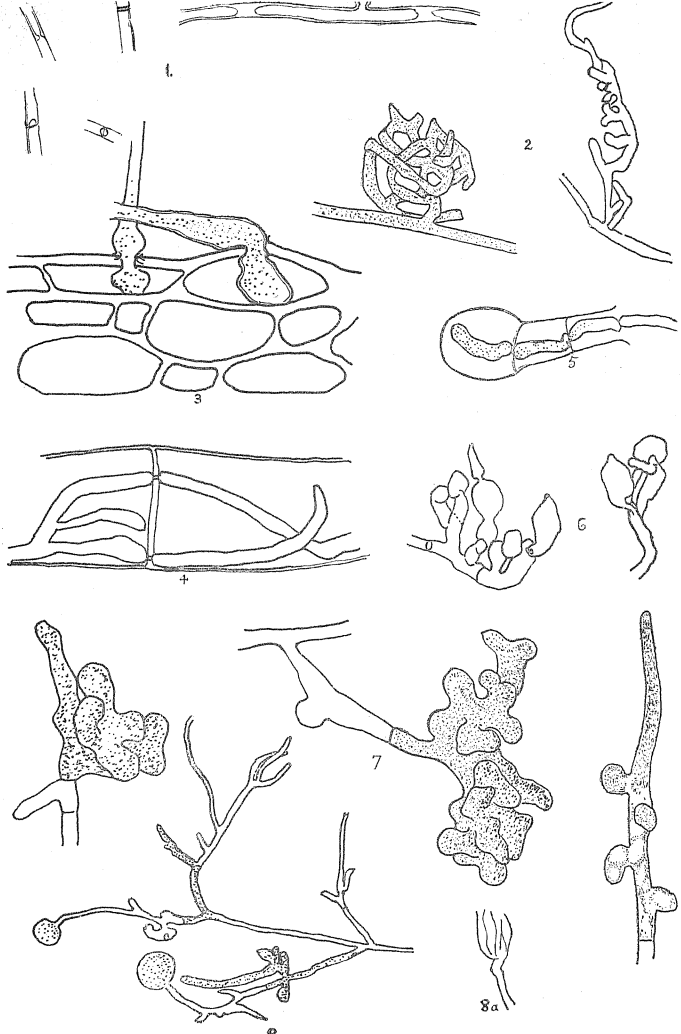
SUMMARY.

Pythium aphanidermatum was isolated from diseased and rotting plants of *Opuntia Dillenii* growing in pots. The fungus induces a wet-rot of the cladodes and is capable of infecting any portion of the plant. Inoculation experiments proved the pathogenicity of the fungus on *Opuntia*. Besides *Opuntia* the fungus is found to be parasitic on a number of other plants.

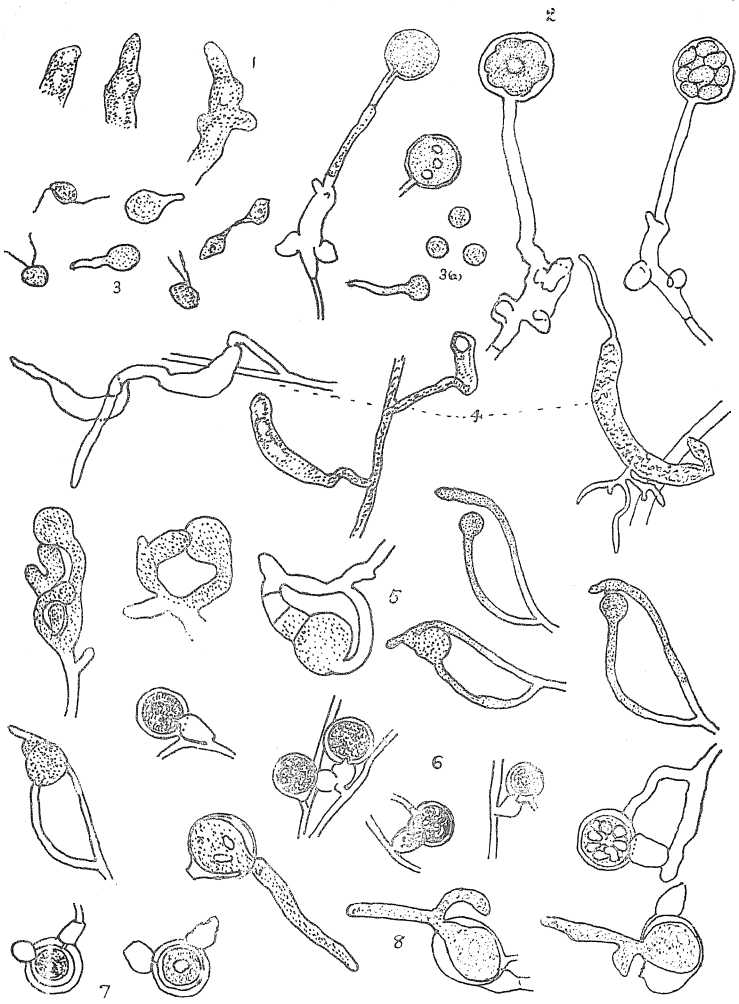
The growth of the fungus on several culture media was studied. Sporangia and oospores are formed in plenty both on solid and liquid media. Sporangia are more numerous in liquid media. Besides the lobulate sporangia, certain curved structures are formed on some media and these are believed to function as conidia.

Comparative studies with *Pythium Butleri* show that *P. Butleri* is a strain of *P. aphanidermatum*.

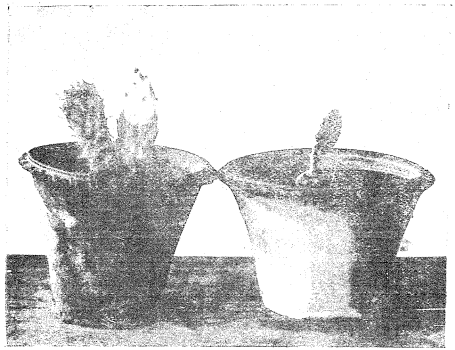
MGIPC—M—III-1-99—5-2-29—650.



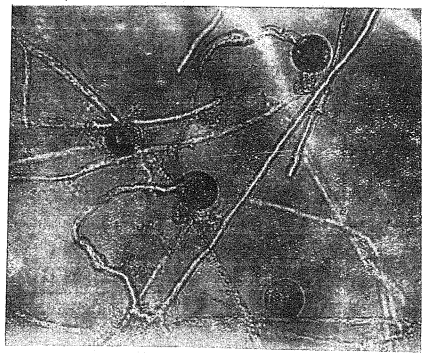
1. Formation of septa and thickenings in hyphae. 2. Masses of coiled hyphae from papaya bits. 3. Section of an Opuntia cladode showing the emergence of hyphae. 4. Hyphae passing through a hair of Opuntia. 5. Hyphae inside a glandular hair from Amaranthus leaf. 6. Swellings of hyphae in Amaranthus extract agar. 7. Different kinds of lobulate sporangia. 8. Sporangial germination. 8-a. Remains of a vesicle after the zoospores are liberated.



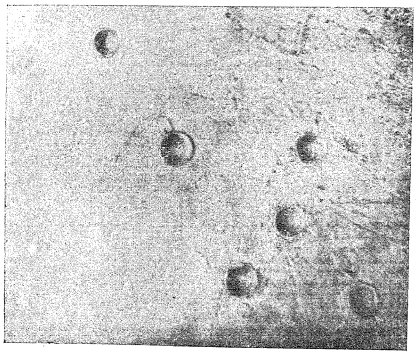
1. Formation of the evacuation tube. 2. Stages in zoospore formation. 3 & 3-a. Zoospores and their germination. 4. Club shaped and falcate structures (probably oonidia). 5 & 6. Antheridia and oogonia and formation of oospores. 7. 2 antheridia attached to one oogonium. 8. Oospore germination.



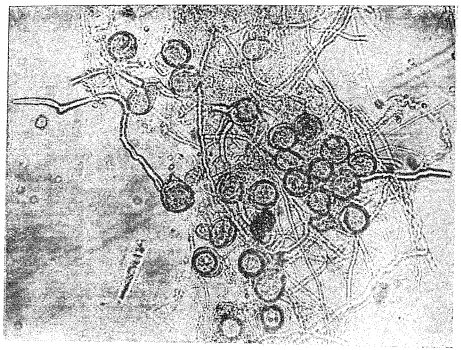
1. Infected *Opuntia* plant and control.



2. Formation of oospore.



3. Oospores.



4. Oospore germination.

PLATE III.